The Canadian Entomologist

VOLUME XCIII NOVEMBER 1961 NUMBER 11

CONTENTS

PUBLISHED MONTHLY

BY THE ENTOMOLOGICAL SOCIETY OF CANADA

AUTHORIZED AS SECOND CLASS MAIL BY POST OFFICE DEPARTMENT, OTTAWA, pp. 91

The Canadian Entomologist

HISTORICAL

An Entomological Society of Canada was founded on April 16, 1863, and was incorporated in 1871 as the Entomological Society of Ontario.

The Canadian Entomologist has been published continuously since 1868. The original Entomological Society of Canada published it until 1871, the Entomological Society of Ontario from 1871 until 1951. A new Entomological Society of Canada was formed in 1951 (see *Can. Ent.* 83: 27-28, 1951), and the two societies published *The Canadian Entomologist* jointly until 1960, when it became the official publication of the Entomological Society of Canada.

SUBSCRIPTIONS

The subscription price is $10.00 per year, payable in advance. This price includes postage but not currency or bank exchange, which must be calculated to yield the full subscription price at Ottawa. Subscribers receive the *Annual Report of the Entomological Society of Ontario*, through the courtesy of the Ontario Department of Agriculture, and also the supplements to *The Canadian Entomologist*. Back numbers beginning with Volume 90 are available at $1.00 per number and $10.50 per volume, including postage; those prior to volume 90 are priced at 75c per number and $6.50 per volume.

Correspondence regarding payments or change of address should be directed to the Treasurer; information on back numbers and exchanges should be obtained from the Secretary.

MEMBERSHIP IN THE ENTOMOLOGICAL SOCIETY OF CANADA

Regular membership is open to all persons interested in entomology. The annual membership fee, payable in advance, is $8.00 for direct membership or $6.00 through a regional affiliate society. Members receive *The Canadian Entomologist* and its supplements and, through the courtesy of the Ontario Department of Agriculture, the *Annual Report of the Entomological Society of Ontario*. Application for membership should be made to the Secretary or to one of the affiliated societies.

Sustaining membership is open to organizations wishing to support the Society for an annual fee of $100.00. Sustaining members receive *The Canadian Entomologist* and may assign to a representative or proxy all privileges of a regular membership except the holding of office.

Student membership at $3.00 is open for one year to university students in the graduating year, on recommendation by the president of a regional affiliated society, or by a professor who is a member of the Entomological Society of Canada. Extension of this privilege for an additional year is permissible on renewed application, subject to approval of the Executive Committee of the Board of Directors.

Articles for publication in *The Canadian Entomologist* are ordinarily accepted only from members of the Society.

ACKNOWLEDGMENTS

Contributions towards the cost of the publication of *The Canadian Entomologist* are received from the Entomological Society of Ontario and Le Ministère de l'Agriculture de la Province de Québec.

The Canadian Entomologist

Vol. XCIII Ottawa, Canada, November 1961 No. 11

Spatial Pattern of the Imported Cabbageworm, *Pieris rapae* (L.) (Lepidoptera: Pieridae), on Cultivated Cruciferae

By D. G. HARCOURT

Entomology Research Institute, Research Branch, Canada Department of Agriculture
Ottawa, Ontario

It is universally recognized that the spatial distribution or pattern of animals and plants in nature is neither uniform nor truly random. In order to study a biological community quantitatively, or to assess the densities of living organisms in their habitats, ecologists have found it profitable to sample the space in which the organisms occur. The distribution of the number of individuals per sample is of fundamental importance.

In the study of insect populations, counts are frequently made of the number of individuals in natural units of their habitat. The counts may be summarized in a frequency distribution showing the number of units containing 0, 1, 2, 3. . . . . individuals of a given species. If a population is distributed over a number of units at random, the distribution of numbers per unit will approximate a Poisson series, the variance of the population being equal to its mean. The Poisson distribution is defined by a single parameter, the arithmetic mean m. Such patterns are rare in nature. Usually there is an excess of unoccupied units and of densely occupied units over Poisson expectation. This departure from randomness is termed "overdispersion".

The distributions most commonly used to describe insect counts are the normal, Poisson, positive binomial, logarithmic, discrete lognormal, Neyman contagious type A, and negative binomial (Waters, 1959). The first three are random; the remainder are non-random and pertain to overdispersed distributions. Of the latter, the negative binomial is the most widely applicable and easiest to compute. It is an extension of the Poisson series and is defined by two parameters, the mean m and an exponent k, which is a measure of dispersion, or alternatively, aggregation. Successive terms of the distribution are obtained by expansion of the expression $(q\text{-}p)^{-k}$, where $p = m/k$ and $q = 1 + p$. As the variance approaches the mean (and the degree of overdispersion decreases), $k \to \infty$, and the distribution tends toward the Poisson. Conversely, as the variance departs from the mean, $k \to 0$, and the distribution converges to the logarithmic series (Fisher *et al.*, 1943). The negative binomial arises from a number of distinct mathematical and biological assumptions (Bliss and Calhoun, 1954; Skellam, 1952). Its statistics have been outlined by several authors, e.g. Fisher (1941), Anscombe (1950), and Bliss and Fisher (1953).

This paper describes the distribution of the immature stages of the imported cabbageworm, *Pieris rapae* (L.), on cruciferous crops, and draws a number of biological implications.

Experimental Plots

The data treated here were collected during 1957 to 1960, largely in connection with long-term studies on the population dynamics of the insect. The counts are from half-acre plots of cabbage at a summer field station[1], Merivale, Ontario, five miles south of the Central Experimental Farm, Ottawa. The plots were marked off by means of a 4 X 4 grid into 16 strata of equal size. On each

[1]For a detailed description of the experimental area see Harcourt (1961).

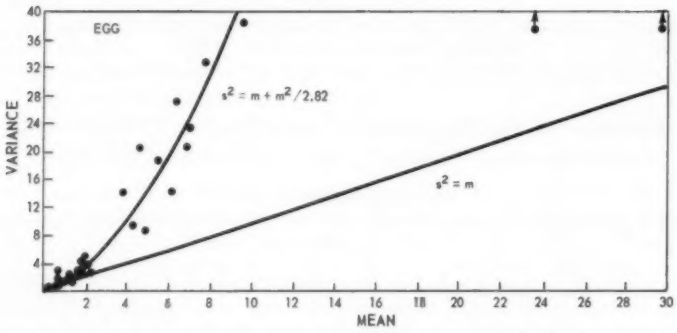


Fig. 1. Variance-mean relationships for counts of eggs of the imported cabbageworm on cabbage. Each point plotted is based on a sample of 64 to 96 plants.

date of sampling, 4 to 6 plants per stratum were examined, depending upon the size of sample needed to obtain predetermined confidence limits. Sample plants were selected at random, sectioned into observational units (quadrants), and examined leaf by leaf. The number of eggs, larvae, and pupae were recorded on each plant, the infestation on individual plants ranging from 0 to 178 and mean densities, from 0.1 to 30.

The experimental crops were grown in accordance with commercial practice. The rows were spaced 36 inches apart with plants at 18-inch centers in the row. Clean cultivation was practised each year, and at no time were insecticides used on or near the experimental plots.

Habits of *P. rapae*

The imported cabbageworm is the familiar, cosmopolitan pierid that attacks cabbage and related crops throughout Canada. Its general biology is rather well known. However, certain of its habits should be mentioned in that they are pertinent to the present study.

Except during inclement weather, the female butterflies are active during most of the daylight hours. They alternately feed and oviposit for brief periods, moving to and from the blooms of wild plants in the immediate vicinity of the cabbage field. The border rows of the crop thus invariably receive more eggs than do those that are centrally located. Hence, plants in border rows were not sampled in the present study. Nor were those off-type, or distorted by feeding of the cabbage aphid, *Brevicoryne brassicae* (L.).

The eggs are laid singly. The caterpillars feed on the foliage of the plants throughout their development, passing through five instars. There is little or no plant-to-plant migration of feeding larvae except in response to crowding at very high density levels. Mature larvae readily migrate from the plants in search of suitable pupation sites, such as fence posts and buildings near the periphery of the field.

Observed Distribution

When Poisson distributions were fitted to the observed distributions, the chi-square test for goodness of fit showed that the discrepancies between observed and expected values were highly significant except at very low population levels. For all stages, the number of uninfested plants exceeded the expected number. In addition, plants containing large numbers of individuals were more numerous than expected. However, the frequencies of all counts approximated the nega-

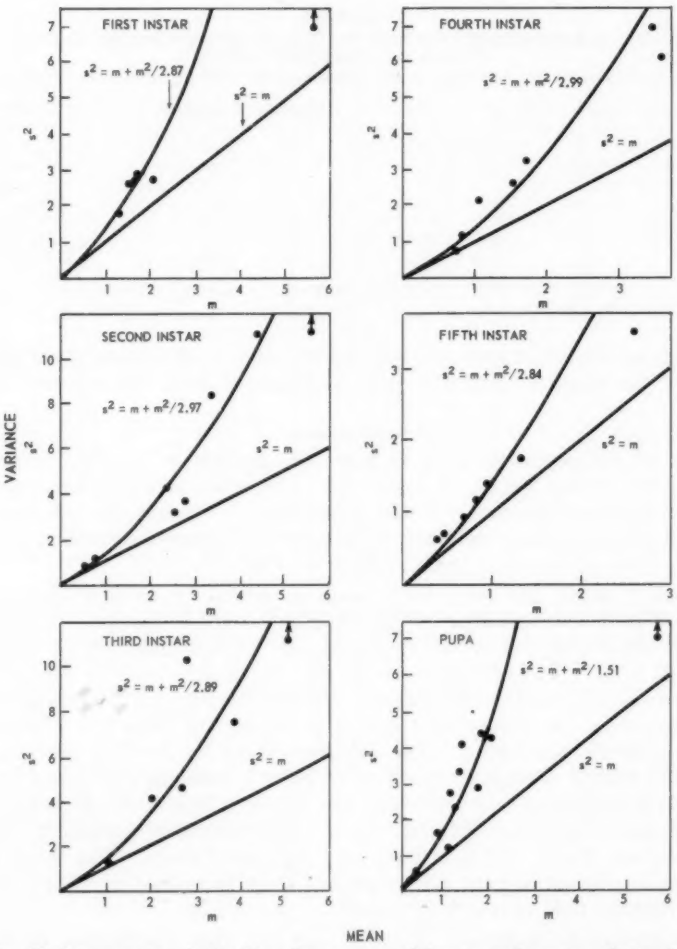


Fig. 2. Variance-mean relationships for counts of larvae and pupae of the imported cabbageworm on cabbage. Each point plotted is based on a sample of 64 to 96 plants.

tive binomial series, and the deviations between observed and expected values did not exceed the five per cent level of significance when the chi-square test was applied.

The variance-mean relationships for 75 representative counts of the immature stages of *P. rapae* are illustrated in figs. 1 and 2. The over-dispersed nature of the data is clearly shown by the plotted values, which depart noticeably from the line of Poisson expectation ($s^2 = m$) to encompass that of negative binomial expectation ($s^2 = m + m^2/k$).

Table I shows the range of means and values of k encountered in the 75 samples, as well as the estimates of common k used in fitting the data. Values of common k were computed by method 1 as described by Anscombe (1949). The individual estimates of k were derived from the formula $k = m^2/(s^2 - m)$, their efficiency varying from 70 to well over 98 per cent (Anscombe, 1950).

TABLE I
Means and estimates of k for immature stages of the imported cabbageworm, Merivale, Ont., 1957-1960[1]

Stage	Range of means	Range of k values	Value of common k
Egg	0.14 – 29.92	0.36 – 12.10	2.82 ± .52
First instar	1.31 – 5.55	1.50 – 5.40	2.87 ± .56
Second instar	0.57 – 5.63	1.02 – 11.36	2.97 ± .89
Third instar	1.08 – 5.13	1.05 – 4.58	2.89 ± .53
Fourth instar	0.73 – 3.61	0.83 – 6.40	2.99 ± .72
Fifth instar	0.40 – 2.63	0.59 – 7.79	2.84 ± .93
Pupa	0.31 – 5.67	0.57 – 5.00	1.51 ± .36

[1]Based on 75 sets of data.

The evidence therefore indicates that the distribution of counts of the immature stages of the imported cabbageworm is consistent with the negative binomial model.

Discussion

Use of the parameter k as an index of aggregation greatly facilitates the analysis and interpretation of insect data. Theoretical values of k can range from zero, where clumping of the population is extreme, to infinity, which defines a purely random distribution of counts. A useful discussion of the attributes of this parameter is given by Waters (1959).

With *P. rapae*, the value for k tends to increase with development of the larvae. This fact is obscured by the range and scope of the data summarized in Table I. However, when larval populations are carefully traced during the course of a complete generation, as in life tables, it is obvious that a gradual approach towards randomness occurs. An example of this is shown in Table II, where the value for k increases from 2.8 in the second instar to 7.8 in the fifth. At this point the distribution is fitted approximately by the Poisson series, giving $\chi^2 = 10.97$ with 5 degrees of freedom ($P = .06$), compared to $\chi^2 = 2.76$ with 4 degrees of freedom ($P = .59$) for the negative binomial. This increase in randomness reflects mortality of larvae due to density-dependent biological control agents, chiefly the virus *Bergoldia virulenta* Tanada. The sharp decrease in k from final instar to pupa (also shown in Table I) reflects migration of mature larvae from the field in search of suitable pupation sites.

As previously indicated (Figs. 1 and 2), the distribution of *P. rapae* approaches the Poisson series at low levels of population. This low degree of aggregation may be attributed to the correspondingly low expectation of occurrence of the insect on individual plants. Table III shows that the Poisson gives a fairly adequate description of the distribution of eggs at densities below two per

TABLE II
Effect of development of *P. rapae* during a single generation on estimates of the parameter k for its immature stages, Merivale, Ont., 1960

Date	Stage recorded	Mean density	Value of k
July 11	Egg	9.5	3.1
July 15	First instar	5.6	2.8
July 18	Second instar	4.4	2.8
July 21	Third instar	4.0	4.6
July 25	Fourth instar	3.6	5.1
July 28	Fifth instar	2.6	7.8
August 3	Pupa	1.7	2.3

TABLE III
Effect of population density on distribution of eggs of the imported cabbageworm, Merivale, Ont.

Date	Mean	Results of χ^2 test		Date	Mean	Results of χ^2 test	
		Negative binomial	Poisson			Negative binomial	Poisson
3/7/59	0.14	x[1]	x	21/7/58	2.27	x	x
5/8/58	0.45	x	x	23/7/60	3.81	x	—
8/8/59	0.69	x	x	12/7/60	4.27	x	—
15/8/58	0.83	x	x	4/7/60	4.55	x	—
10/9/57	0.86	x	x	19/7/60	4.86	x	—
3/9/57	0.88	x	x	15/8/60	5.51	x	—
14/7/58	1.12	x	x	29/7/59	6.22	x	—
3/8/57	1.18	x	x	13/7/59	6.34	x	—
26/6/59	1.51	x	—[2]	15/7/60	6.88	x	—
7/7/59	1.60	x	—	29/6/59	6.92	x	—
27/8/57	1.71	x	x	14/7/60	7.78	x	—
5/8/57	1.72	x	x	11/7/60	9.50	x	—
7/7/57	1.84	x	x	6/8/57	23.55	x	—
29/7/60	2.09	x	—	13/8/57	29.92	x	—
17/7/58	2.15	x	—				

[1]Deviations from expectation not significant at 5 per cent level.
[2]Deviations from expectation significant at 5 per cent level.

plant. On the other hand, there is little evidence of agreement with the Poisson distribution at mean densities above two. The values of k for the highest two populations shown in Table III, i.e. 23.55 and 29.92, were low, 2.74 and 1.35, respectively, suggesting that saturation of oviposition sites does not occur at densities below 30 per plant.

It has been pointed out by Pielou (1957) and Waters and Henson (1959) that the size of sampling unit may affect the skewness of over-dispersed distributions. Accordingly, several sets of data were tabulated according to three progressively larger observational units. Estimates of k for each stage were as follows:

Unit of observation	Egg	Instar					Pupa
		First	Second	Third	Fourth	Fifth	
Quadrant	1.06	1.38	1.81	1.40	1.96	2.97	2.14
Half plant	1.28	2.28	2.91	1.81	4.24	2.81	2.78
Whole plant	1.29	2.32	2.79	2.24	4.28	3.50	2.25

It is evident that the k values are affected by size of the observational unit. This additional source of heterogeneity may be attributed to the egg-laying habits of the adult. The female butterflies are weak fliers and are readily buffeted by the wind. To maximize flight stability during windy periods of the day, they work their way across the field in an up-wind direction, ovipositing on the leaward side of the plants. This results in quadrant-to-quadrant differences in egg populations. This aggregative effect becomes less pronounced as the larvae mature and spread out over the plants. When the data are tabulated according to

half plants, using the lee quadrant and the one adjacent to it, the intra-plant variation is largely removed.

Evans (1952) showed that modifications in the size of sampling unit may change the type of the frequency distribution. This was not observed in the present study; when fitted to the negative binomial series, the data tabulated both by quadrants and half plants did not show any significant differences between observed and expected values.

It may be concluded that the negative binomial gives an adequate description of the frequency distribution of counts of the imported cabbageworm on cabbage. Except for the occasional outlying value (e.g. 12.10 and 11.36, Table I), the parameter k remained reasonably stable with variation in m for each stage of the insect. Furthermore, only slight modification of the parameter resulted when populations were stratified according to two density levels:

Number of individuals per plant	Mean k values		
	Egg	Larva	Pupa
<3	2.8	2.8	1.4
>3	3.0	3.1	2.2

The tendency for k to increase with m was also observed in populations of *P. maculipennis* on the same host crop (Harcourt, 1960), and appears to be typical of insect distributions that conform to the negative binomial series (Anscombe, 1948, 1949; Morris 1955; Waters, 1959).

Distribution of *P. rapae* on Other Crucifers

Data collected in 1954 at Merivale in an experiment on attractiveness to *P. rapae* of several varieties of cultivated crucifers were fitted to both the Poisson and negative binomial series. When observed and expected values were compared, the chi-square test showed that the negative binomial was the more appropriate distribution for populations of the insect on the following: cauliflower, broccoli, brussels sprouts, kale, kohlrabi, and collards.

Transformation of Counts for Analysis of Variance

The analysis of variance model presupposes a frequency distribution of the normal type in which the variance is independent of the mean. Many transformations have been proposed for stabilizing the variance of negative binomial distributions. Most widely applicable is the logarithm of $(x + 1)$, where x is equal to the observed count (Wadley, 1950). Anscombe (1948) has suggested the logarithm of $(x + k_2)$. The appropriate transformation may be expected to lead also to additivity (Bliss and Owen, 1958).

The most suitable transformation for counts of the immature stages of the imported cabbageworm will be the one that best stabilizes the variance, i.e., makes the variance most independent of the mean. To determine the effect of transformation upon this relationship, several of the 75 sets of data were transformed using the logarithms of $(x + 1)$ and $(x + k_2)$ (one example given, Table IV). Table IV shows that the correlation coefficient between the means and the variances was highly significant when the original counts were used, but not significant when the counts were transformed to log $(x + 1)$, or log $(x + k_2)$. It may therefore be concluded that either transformation is satisfactory for

TABLE IV

The mean and variance of counts of eggs of the imported cabbageworm, Merivale, Ont., July 15, 1960

Plot	Original counts (x)		Transformed [log (x+1)]		Transformed [log x+(k/2)]	
	Mean	Variance	Mean	Variance	Mean	Variance
1	8.33	17.00	.939	.031	.979	.026
2	10.16	47.80	.966	.096	1.010	.077
3	7.16	13.38	.881	.031	.926	.026
4	6.50	37.10	.717	.199	.804	.133
5	7.16	19.37	.839	.094	.895	.068
6	7.33	34.69	.834	.089	.890	.071
7	8.50	19.50	.905	.101	.957	.074
8	4.66	5.87	.719	.036	.785	.027
9	7.50	40.30	.778	.206	.858	.137
10	7.16	19.97	.858	.058	.909	.046
11	7.16	6.17	.898	.013	.941	.011
12	7.50	27.90	.845	.102	.902	.076
13	5.50	8.30	.774	.042	.834	.032
14	6.60	21.10	.768	.138	.840	.098
15	4.50	2.70	.722	.021	.786	.015
16	6.33	36.27	.769	.091	.833	.072
	$r = 0.730$		$r = -.277$		$r = -.130$	

counts of the imported cabbageworm that are to be subjected to analysis of variance.

Summary

Except at very low population densities, counts of the immature stages of the imported cabbageworm on cruciferous crops did not conform to the Poisson distribution, there being an excess of uninfested plants over the expected number. Also, there was an excess of heavily infested plants. However, when the observed distributions were fitted to the negative binomial series, the chi-square test for goodness of fit indicated close agreement. The distributions of the various stages may be described as follows: egg $(q - p)^{-2.88}$, first instar $(q - p)^{-2.87}$, second instar $(q - p)^{-2.97}$, third instar $(q - p)^{-2.89}$, fourth instar $(q - p)^{-2.99}$, fifth instar $(q - p)^{-2.84}$, pupa $(q - p)^{-1.51}$.

Aggregation resulted from initial non-random deposition of eggs. Randomness during a given generation increased with development of the larvae due to differential elimination of the insect by biological control agents, but decreased at pupation due to the migratory habits of mature larvae.

Examination of the negative binomial parameter k showed that it was reasonably independent of density, but could be affected by the size of observational unit. Transformation of the data using log $(x + 1)$ or log $(x + k_2)$ stabilized the variance satisfactorily for analysis of variance.

Acknowledgments

The author is indebted to Dr. K. E. F. Watt, and Mrs. P. M. Morse, Statistical Research Service, Ottawa, for criticizing the manuscript, and to Mr. L. M. Cass for routine statistical analyses.

References

Anscombe, F. J. 1948. The transformation of Poisson, binomial and negative-binomial data. *Biometrika* 35: 246-254.

Anscombe, F. J. 1949. The statistical analysis of insect counts based on the negative binomial distribution. *Biometrics* 5: 165-173.

Anscombe, F. J. 1950. Sampling theory of the negative binomial and logarithmic series distribution. *Biometrika* 37: 358-382.
Bliss, C. I., and R. A. Fisher. 1953. Fitting the negative binomial distribution to biological data. *Biometrics* 9: 176-200.
Bliss, C. I., and D. W. Calhoun. 1954. An outline of biometry. Yale Cooperative Corp., New Haven.
Bliss, C. I., and A. R. G. Owen. 1958. Negative binomial distributions with a common *k*. *Biometrika* 45: 37-58.
Evans, F. C. 1952. The influence of size of quadrat on the distributional patterns of plant populations. Contrib. Lab. Vert. Biol., Univ. Michigan No. 54.
Fisher, R. A. 1941. The negative binomial distribution. *Ann. Eugenics* 11: 182-187.
Fisher, R. A., A. S. Corbett, and C. B. Williams. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. *J. Animal Ecol.* 12: 42-58.
Harcourt, D. G. 1960. Distribution of the immature stages of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae), on cabbage. *Canadian Ent.* 92: 517-521.
Harcourt, D. G. 1961. Design of a sampling plan for studies on the population dynamics of the diamondback moth, *Plutella maculipennis* (Curt.) (Lepidoptera: Plutellidae). *Canadian Ent.* 93: 820-831.
Morris, R. F. 1955. The development of sampling techniques for forest insect defoliators, with particular reference to the spruce budworm. *Canadian J. Zool.* 33: 225-294.
Pielou, E. C. 1957. The effect of quadrat size on the estimation of the parameters of Neyman's and Thomas's distributions. *J. Ecol.* 45: 31-47.
Skellam, J. G. 1952. Studies in statistical ecology. I. Spatial pattern. *Biometrika* 39: 346-362.
Wadley, F. M. 1950. Notes on the form of distribution of insect and plant populations. *Ann. Ent. Soc. America* 43: 581-586.
Waters, W. E. 1959. A quantitative measure of aggregation in insects. *J. Econ. Ent.* 52: 1180-1184.
Waters, W. E., and W. R. Henson. 1959. Some sampling attributes of the negative binomial distribution with special reference to forest insects. *Forest Sci.* 5: 397-412.

(Received May 3, 1961)

The Life History and Habits of a Midge, *Contarinia oregonensis* Foote (Diptera: Cecidomyiidae) in Douglas-fir Cones[1]

By A. F. HEDLIN
Forest Biology Laboratory, Victoria, B.C.

Introduction

A midge, *Contarinia oregonensis*, is one of a number of species of insects which cause seed losses in Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco. In recent years it has been reported causing more damage than any other single species of Douglas-fir cone insect in western Washington (Johnson and Heikkenen, 1958). This has been the situation on Vancouver Island also.

The species was described by Foote (1956) from specimens taken in Oregon in 1916.

Midges have been recognized in Douglas-fir cones for many years but were not reported causing serious damage until recently. Miller (1914) working in Oregon reported that larvae of gnats or midges cause small masses of resin to form among the cone scales without causing much damage to the seed. Rudinsky (1955) in Washington observed midges forming galls in scale tissue of Douglas-fir cones but recorded little damage to seed. Keen (1958) reported that in Oregon in 1917 larvae were found in galls at the base of cone scales. In 1941

[1]Contribution No. 721, Forest Biology Division, Department of Forestry, Ottawa, Canada.

TABLE I
Dimensions of the different stages of *C. oregonensis*

Stage	No. insects	Measurements (range) (mm.)
Egg	11	Length 0.26 (0.23 - 0.29) Width 0.08 (0.07 - 0.09)
Larva (instars)		
I	79	Length 0.32 (0.12 - 0.56)
	18	Head capsule width 0.029 (0.026 - 0.032)
II	13	Length 1.11 (0.57 - 1.69)
	30	Head capsule width 0.059 (0.052 - 0.065)
III	17	Length 2.82 (1.30 - 4.07)
	11	Head capsule width 0.074 (0.069 - 0.077)
	15	Sternal spatula length 0.24 (0.23 - 0.25)
	14	Sternal spatula width 0.069 (0.065 - 0.078)
Pupa		
♂	17	Length 2.50 (2.01 - 2.71)
♀	18	Length 2.70 (2.08 - 3.08)
Cocoon		
♂	17	Length 2.98 (2.59 - 3.35) Width 1.14 (0.99 - 1.29)
♀	18	Length 3.24 (2.46 - 3.64) Width 1.23 (1.03 - 1.42)
Adult (preserved specimens)		
♂	10	Length 2.96 (2.45 - 3.69)
♀	10	Width 4.00 (3.84 - 4.12)

Graham and Prebble[2] observed galls and resulting seed loss caused by midges. More recent observations reporting appreciable damage to seed have been made by Johnson (1956 and 1958), Johnson and Heikkenen (1958) in Washington, and Koerber (1960) in California.

The observations and experiments recorded here were made from 1957 to 1960 in the Cowichan Lake area of Vancouver Island and at Victoria, B.C.

Since *C. oregonensis* is completely dependent on the cone of its host as an oviposition site and source of food during its larval stage, it seems fitting to include a short account of the fruiting habits of Douglas fir.

Douglas fir is monoecious, female flowers usually occurring in the upper portion but may be found over the whole crown. Male flowers are usually more plentiful in the lower portion of the crown. Cones are produced only on branchlets which were formed the previous year. Flower buds burst early in the spring, usually in the latter half of April in the Cowichan Lake area of Vancouver Island. The new female flowers (Fig. 1) stand erect on the twig with the cone scales open. It is during this stage that the flower is pollinated. After a period of a week or 10 days the cone scales become appressed. At the same time the flower turns slowly through a horizontal position to become pendant about one month from the time of bud burst. It remains pendant for the remainder of its development. Cones mature in one season but may persist for one or more years before dropping. Cone crops may fluctuate considerably from year to year.

Description of stages

Egg.—(Fig. 9) The egg is oblong with a short tail at the posterior end. Freshly laid eggs are smooth, shiny, and white. When development has started the embryo can be seen clearly through the chorion. Dimensions of the egg and the other stages of the insect are given in Table I.

Larva.—(Fig. 18 a, b, c) The larva passes through three instars. The first is almost colourless early in development, but later yellow fat bodies and black

[2]Unpublished data.

"eye-buds" are clearly visible. Spiracle distribution is metapneustic. The second-instar larva is similar in colour to the first but is more easily detected in the cone scale because of its larger size. Small hooks are visible on the last abdominal segment. Spiracles are arranged peripneustically in both the second and third instars. A sternal spatula is present on all third-instar larvae. Only the anterior lobes of the spatula are present immediately after the second moult but in a few weeks it is completely developed (Fig. 2). In this instar the insect acquires the orange colour which is characteristic of the mature larva. The anal hooks which appeared in the second instar are fully developed. The U-shaped position is always assumed by the third-instar larva in the gall (Fig. 12) and often in the cocoon (Fig. 11).

Prepupa.—The prepupal and pupal stages are passed in a cocoon (Fig. 4). Following pupation a number of cocoons were measured, then the insects were removed and sexed. The data in Table I show that cocoons spun by female larvae are larger than those spun by male larvae. When newly formed, the cocoon is light in colour and semitransparent but it soon becomes dark brown and papery with an uneven surface. The larval in it shortens and thickens.

Pupa.—(Fig. 7) Early in development the pupa is orange in colour but later the eyes become deeply pigmented changing from dark red to black. The wing pads, abdomen, legs, and thorax gradually become darker in colour. The thoracic horns sometimes protrude from the cocoon (Fig. 4). These apparently aid in pushing off the end of the cocoon as the adult emerges. A delicate case (Fig. 15) is shed immediately after the insect wriggles out of the cocoon.

Adult.—The delicate adult has long legs and antennae. The funicle of the antenna is 12-segmented and in the male each segment is strongly constricted in the centre but in the female only moderately constricted. When the insect is at rest the antennae curl upwards and the wings lie flat over the abdomen. The abdomen is orange in colour. The female has a long retractile ovipositor.

Gall.—The gall is usually formed in the vicinity of the ovules (Fig. 16) and the number of larvae in one gall may range from one to 30. Larvae develop in individual chambers producing a polythalamous gall. When a number of larvae are present they destroy the ovules. When only a few larvae form the gall, the seed may develop but becomes tightly fused to the cone scale. Occasionally a small gall forms in the scale some distance from the seed. This is caused by larvae from eggs deposited after scales are appressed and which are remote from the ovules.

Life History and Habits

The adult insect emerges from the cocoon in the litter in early spring when Douglas-fir flower buds are bursting. The female deposits eggs near the base of the cone scale in the newly opened flower. When the eggs hatch, the larvae tunnel into the young cone scale and form a gall or swollen area near the ovules. Larvae have completed feeding by the time the cone matures. They leave the cone in the autumn to spin cocoons in the litter and overwinter as prepupae and pupae.

Figs. 1-8. 1. Young male and female Douglas-fir flowers. 2. Fully developed sternal spatula of third-instar *C. oregonensis* larva. 3. Polythene traps below tree to catch emerging *C. oregonensis* larvae. 4. *C. oregonensis* cocoons showing protruding pupal thoracic horns. 5. Douglas-fir cones suspended over polythene traps. 6-8. *C. oregonensis*. 6. Cocoons in cotton batting; 7. Pupa removed from cocoon; 8. Eye-buds separating during prepupal development; a-d, dorsal view; a—early; b, c—separating; d—moving ventrally; e—late, ventral view.

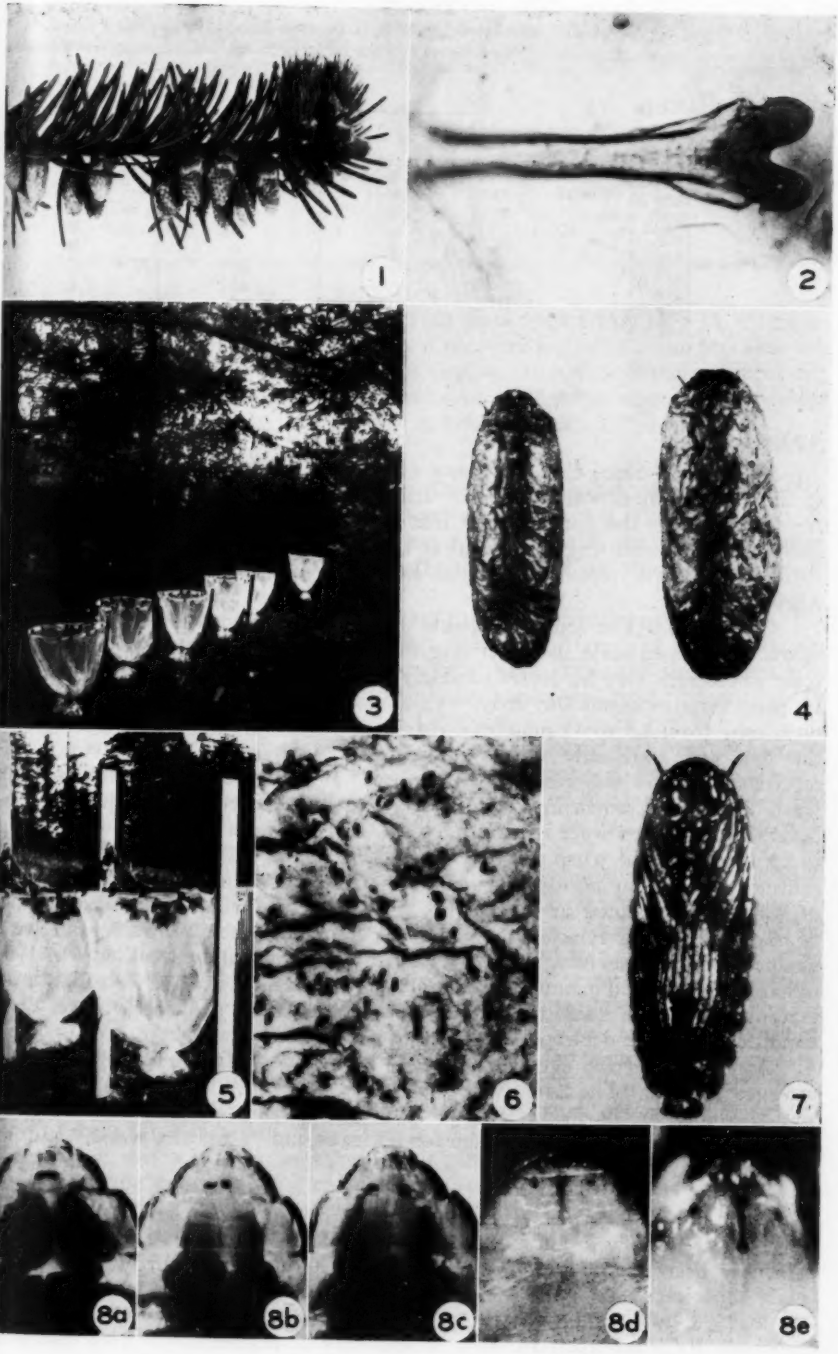

1
2
3
4
5
6
7
8a
8b
8c
8d
8e

TABLE II
C. oregonensis larval development, Robertson River, 1960.

Date	No. larvae in instar		
	I	II	III
June 22	8	0	0
June 30	14	2	0
July 5	1	9	0
July 7	6	23	0
July 8	3	6	0
July 12	0	31	3
July 15	0	11	4
July 26	0	0	13
Aug. 4	0	0	18
Aug. 12	0	1	17
Aug. 22	0	0	20

Adult

Emergence.—Since the emergence of the adult coincides with development of the Douglas-fir flowers, the time varies with the area and elevation. Adults are active during the entire period that flowers are being pollinated. In 1960, adults emerged from caged material at Cowichan Lake from May 4 to 25. In 1958, when warm weather occurred earlier, eggs were observed as early as April 16.

Oviposition.—The female oviposits in the newly opened flower by backing below the opened scale and extending the flexible ovipositor to the base of the scale where eggs may be deposited singly but usually in clusters. The time that an insect remains in one site varies. One female was timed in different locations on a cone from 1.5 to 33 minutes. Adults are active in the field at all times of the day and apparently work continuously. Ovipositing females were observed at different times from 9.00 a.m. to 7.30 p.m. P.S.T. The temperature was about 10° C. when most of the activity was observed, but at higher temperatures the insects were also very active. In 1960 the weather was wet during much of the period when adults were active but this did not seem to deter the females because they continued to oviposit while light rain was falling and drops of water had collected in the flowers. Although rainfall did not seem to discourage ovipositing females, some became stuck to cones by water and were unable to free themselves. Activity decreased during windy weather. In 1960 oviposition occurred from May 5 to 18 at Cowichan Lake. Oviposition may continue until cone scales are appressed and cones almost pendant. Under these conditions eggs are deposited in the angle between bract and scale.

An average of 238 eggs was removed by dissection from each of six newly emerged females. The range was 119 to 396.

Male and female insects reared in screen-top jars in the laboratory lived from one to six days. The average for 60 males and 71 females was 2.9 and 3.7 days, respectively.

Egg

Eggs are usually in clusters near the base of the cone scale. More than 100 eggs have been observed in a single cluster. The highest number recorded in a single cone was 1690.

In 1958, 1959, and 1960, eggs were first observed in cones in the field at Cowichan Lake on April 16, May 6, and May 2, respectively. First hatching

TABLE III
Duration of larval instars of *C. oregonensis* as indicated by first appearance of instars in 1959 and 1960, Robertson River, B.C.

	Period		Duration	
	1959	1960	1959	1960
First hatch - first 2nd instar	May 5 - June 19	May 15 - June 30	45 days	46 days
First 2nd - first 3rd	June 10 - July 1	June 30 - July 12	20 days	12 days
First 3rd - prepupa	July 1 - Dec.	July 12 - Dec.	6 mos.	6 mos.

dates recorded for the years 1958 and 1960 were May 5 and May 15. This indicates an incubation period of two to three weeks. When first hatching was recorded, cones were in the horizontal position and all scales were appressed. Final hatching dates are difficult to obtain. In 1960, a few eggs, some of which still appeared to be viable, were present in cones on June 9.

Larva

Development.—A record of larval development based on observations in 1960 is shown in Table II. A single second-instar larva was taken on August 12, almost one month later than others in that instar, but since this date is obviously abnormal it was not used in calculating the duration of the second instar shown in Table III.

First-instar larvae are present in cones for approximately eight weeks. The duration of the instar is about six weeks. Presence of larvae in the scale at the end of this period is indicated by the smooth, shiny, colourless surface near the ovule which is characteristic of early gall information and appears first near the end of May.

For a short period after moulting the insect is flaccid but soon assumes its normal firm appearance. The second-instar larva continues to feed in the selected location forming a small chamber in the scale. Some assume the U-shaped position which is characteristic of the third-instar larva in its chamber (Fig. 12). The duration of the instar is about two weeks.

The second moult occurs during the first half of July. The larva increases in size during the third instar and changes in colour from dull white to orange. The larva remains in this instar for about six months. It is during this period that it leaves the gall in the cone to enter the litter and spin a cocoon.

From the beginning of egg hatching until the first moult, the cone turns from the horizontal position when it is a few centimetres long and the scales are watery and turgid, to the pendant position when the scales are becoming tough and fibrous. During the remainder of larval development the cone remains pendant. It becomes dry and hard soon after maturity.

Feeding.—Felt (1925) states that gall midge larvae obtain most of their nourishment by absorption. The absence of any sign of feeding in the gall indicates that this is true for this species. Figure 17 shows chambers formed by larvae in scale tissue. Larval chambers ranged in size from 1.44 to 2.25 mm. long and 0.72 to 1.12 mm. wide (19 measurements).

Habits.—The newly hatched larva migrates slowly along the inner surface of the cone scale. Entry into scale tissue commences a few days after hatching but the larva remains near the surface for some time. The insect can be detected by the colourless tunnel in the light green scale tissue, and by the dark eye-buds and yellow fat bodies in the larva. The first-instar larva tunnels from

the point of entry in the scale tissue to a point usually near an ovule, where a gall soon begins to form (Fig. 19). Larvae may tunnel along the surface of the ovule but never settle down to form a gall in ovule tissue.

Larvae leave the mature cones in the autumn. According to Sen (1939) the function of the sternal spatula in a related species, *Rhabdophaga saliciperda* Duf., is to aid the larva in emerging from the gall. The spatula is used to burrow an exit hole. This could be true for *C. oregonensis* because the ventral surface on which the spatula is located is always on the outside or exposed surface of the U-shaped larva in the gall chamber, and in this position the spatula could readily be used for burrowing.

Larvae will not leave the cones until the latter become wet. Larvae did not leave dry cones overwintered in the laboratory at Cowichan Lake in 1959-60. Early in May a few of these cones were soaked in water and the following day a number of larvae emerged. Ten days later all had entered cotton batting on which they had been placed, and had spun cocoons. In November, larvae were still present in cocoons in the batting.

In 1958 an experiment was carried out under controlled conditions for information on emergence of mature larvae from cone scales. Infested scales were held at four moisture levels and at five temperatures. Four groups of 80 infested scales were air dried. Then one group was soaked in water for six hours (saturated), another for 90 minutes (wet), and another for five minutes (moist). The fourth group was left dry (dry). Each group was divided into sub-groups of 16 and sealed in polythene bags. One bag from each group was stored at temperatures of 0, 5, 10, 15, and 20° C.

Figure 20 shows, for each group of infested scales, the total number of insects, the number emerged and the percentage of the total emerged at each of the temperatures. Figure 21 shows the period of emergence for different conditions. Disregarding temperature differences, percentage emergence of larvae at different degrees of wetness was as follows: dry – 0, moist – 18.5, wet – 65.7, and saturated – 76.5. At different temperatures the percentage emergence was: 0° – 37.6, 5° – 49.6, 10° – 51.0, 15° – 41.8, and 20° – 21.0.

These data show that no larvae emerged from dry cone scales and that emergence increased as degree of moisture was increased. Emergence was highest in the middle of the temperature range tested with a pronounced decrease at the highest temperature.

Following this controlled experiment, a field study was conducted to obtain information on period of larval emergence from cones under natural conditions. In September, 1959, infested cones were suspended over polythene "traps" (Fig. 5) and larval emergence was recorded daily. A tree near Victoria, 31 feet high with a crown radius of 15 feet bearing severely infested cones, was selected. Eighteen polythene traps two feet in diameter were placed at about four-foot intervals from four to 29 feet on three lines radiating from the base of the tree (Fig. 3). Larval emergence was recorded and precipitation and temperature records were obtained from the Victoria City Weather Office, Gonzales Observatory, Department of Transport, Victoria. Larvae commenced emerging from cones which were suspended over traps, on September 19, when 0.34 inches

Figs. 9-17. 9. *C. oregonensis* eggs, embryo well-developed. 10. *Platygaster* sp., puparia. 11, 12. *C. oregonensis*. 11. Third-instar larva in U-shape in cocoon. 12. Third-instar larva in gall. 13. *Torymus* sp., well-developed embryo in egg. 14. *Platygaster* sp., young larva feeding within host. 15. *C. oregonensis* cocoon from which adult has emerged. 16. Emergence holes of *Torymus* sp. from *C. oregonensis* gall. 17. Section of Douglas-fir cone infested by *C. oregonensis*.

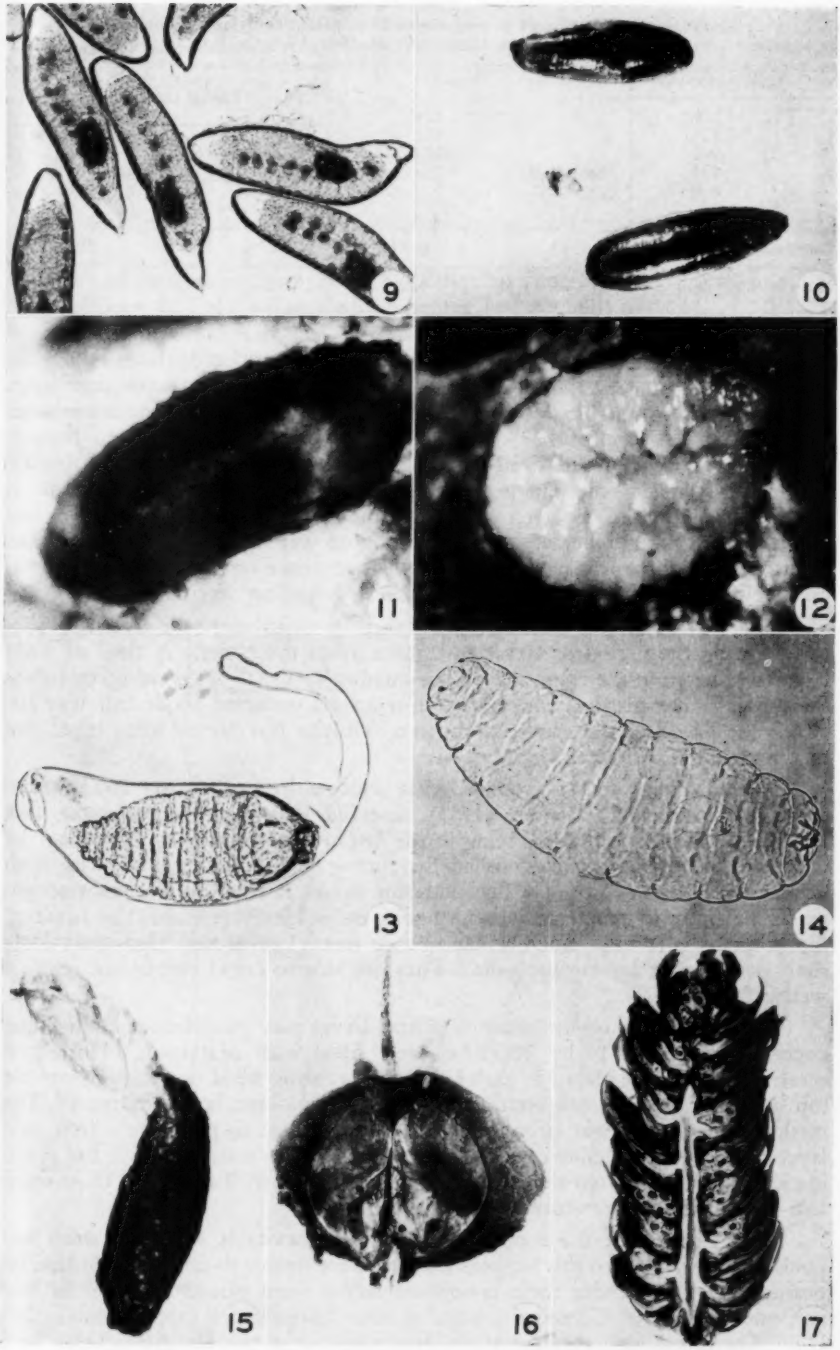

9
10
11
12
13
14
15
16
17

TABLE IV
Summary of emergence of *C. oregonensis* larvae from Douglas-fir cones and rainfall from Sept. 19 to Nov. 30, 1959, Victoria, B.C.

	No. days	Av. precip. per day	Larval emergence		
			Days occurred		No./day (av.)
			No.	%	
Days with rain	45	0.21	39	87	201
Days without rain	28	0.0	12	43	8

of rain fell. Precipitation for the 10 days immediately prior to this was 0.0, 0.0, 0.0, 0.0, 0.0, 0.10, 0.0, 0.03, 0.05, and trace. Figure 22 shows daily larval emergence recorded in traps and its relationship to precipitation and maximum-minimum temperatures. A total of 4,237 larvae was taken from September 19 to January 21, but 99 per cent of these had emerged by the end of November. Table IV summarizes some of the emergence and precipitation data for this period. It shows that emergence occurred on most of the days for which precipitation was recorded, and the number of larvae emerging on wet days was far greater than on days when there was no precipitation. Emergence on days when there was no precipitation usually occurred immediately following wet days.

Figure 23 shows dispersal of larvae taken in traps below the tree near Victoria, during the period of larval emergence from the cones. A total of 4,634 larvae was taken in the traps and of this number 4,416 (95%) were taken below the crown. The greatest concentration of insects occurred about half way between the base and the crown perimeter. Only a few larvae were taken five feet beyond the perimeter of the crown.

After dropping to the ground, larvae select a site in the litter and spin cocoons. Johnson and Winjum (1960) observed that many larvae enter male Douglas-fir flowers which are lying in the litter. They move by "skipping" or crawling. Skipping is accomplished by curling into an inverted U with both extremities on the substrate. The posterior hooks fasten near the anterior and when the body is under tension the hooks are suddenly released; the resulting flip propels the larva as much as one or two feet. Larvae skip vigorously for a short period after leaving the galls. They are able to crawl slowly but only on wet surfaces.

For information on the depth to which larvae may go before spinning their cocoons, two boxes 14 by 20 inches were filled with peat moss. Horizontal screen dividers were placed in each box as it was being filled to provide from the top downwards, three one-inch layers and two two-inch layers of moss. The mesh of the screens was large enough to allow larvae to pass freely from one layer to the next, yet allowed each layer to be lifted as a discrete unit for examination. The data from the two tests are combined in Table V. They show that most of the larvae remained in the upper layers.

Since larvae leave the cones in wet weather, inevitably a number drop into pools of water. When this happens the larvae are unable to escape. For data on possible mortality under these conditions larvae were placed in water in two jars, one kept at 10° C., and the other at room temperature (approximately 20° C.). There was high survival of the larvae reared at 10° C. After being held

TABLE V
Vertical distribution of *C. oregonensis* cocoons in peat moss.

Depth (inches)	No. cocoons	Percentage of total
0 - 1	1495	84.3
1 - 2	226	12.7
2 - 3	35	2.0
3 - 5	17	1.0
5 - 7	0	0.0

under these conditions from Nov. 20, 1959, to June 3, 1960, a period of 6½ months, only 37 (14%) had died, and three had actually pupated. Under the warmer conditions experienced by 97 larvae at room temperature, mortality occurred more rapidly. After a period of four months all had died. Under field conditions, temperatures to which larvae would normally be exposed during hibernation would range from 0° to 10° C.

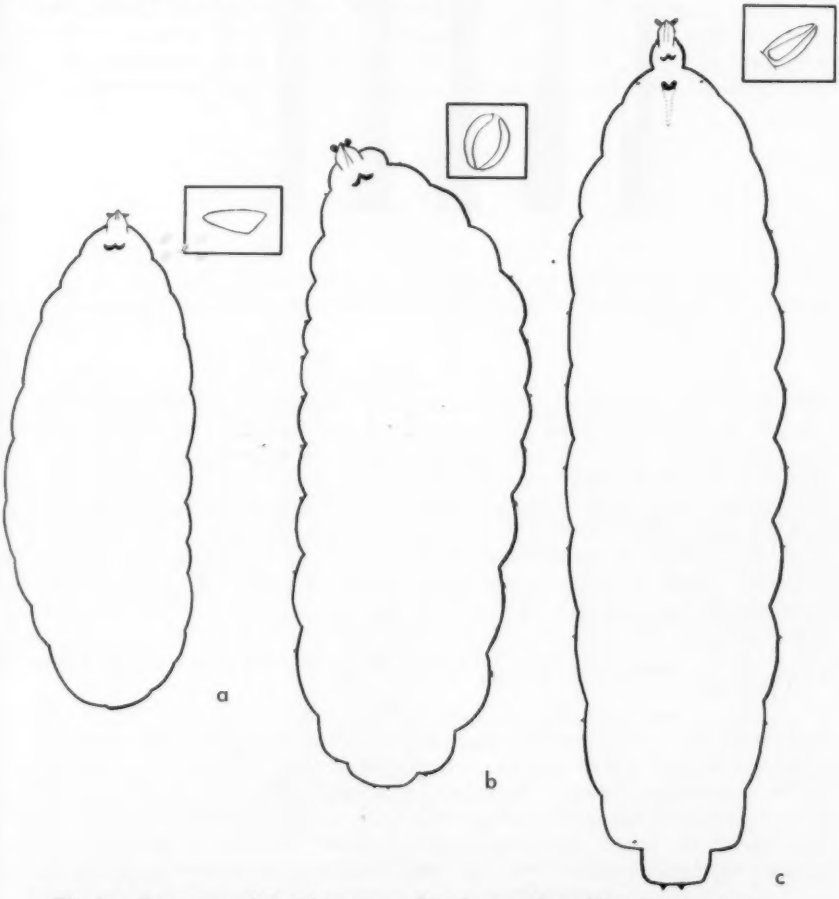


Fig. 18. *C. oregonensis* larval instars; a, first; b, second; c, third; antennae inset.

TABLE VI
Duration of prepupal and pupal stages of *C. oregonensis* reared at different temperatures, Victoria, B.C., 1959-60.

Temp. (°C.)	First dates			Duration of stage (wks.)	
	Prepupa	Pupa	Adult	Prepupa	Pupa
5	Dec. 21	Feb. 8	—	7	—
9	Dec. 21	Feb. 15	Apr. 4	8	7
13	Dec. 21	Feb. 15	Apr. 4	8	7
Outdoors 0-10	Dec. 22	Feb. 22	Apr. 7	9	6.5

The larva selects its site and spins a cocoon a few days after leaving the gall. In the cocoon it may assume a position similar to that taken within the gall or it may be partly or fully extended.

Prepupa

After emerging from the cones, larvae will enter wet cotton batting readily and spin their cocoons (Fig. 6). Insects which had spun cocoons in batting were kept at 5°, 9°, 13° C. and outdoor temperatures from November 26, 1959 until April 18, 1960 for observations on prepupal and pupal development. Pre-

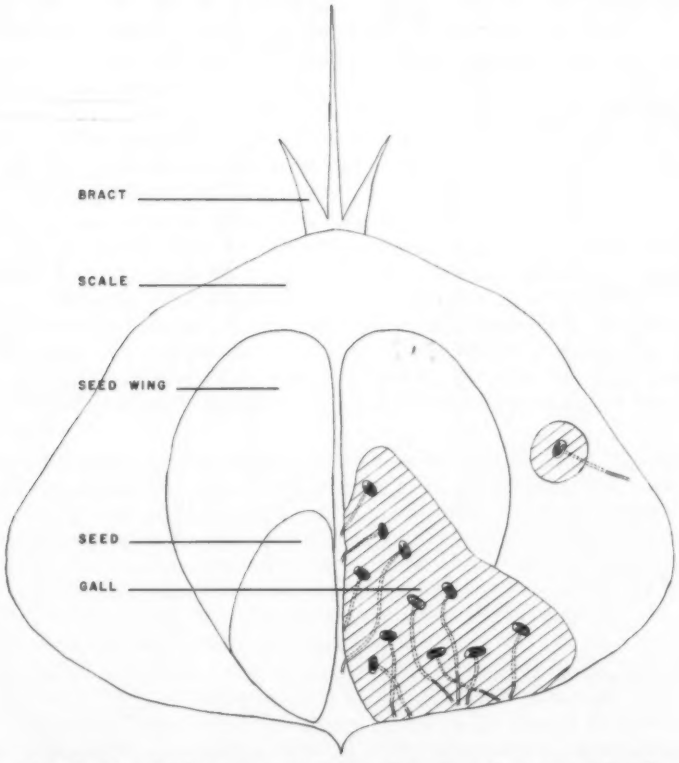


Fig. 19. Douglas-fir cone scale illustrated to show *C. oregonensis* gall.

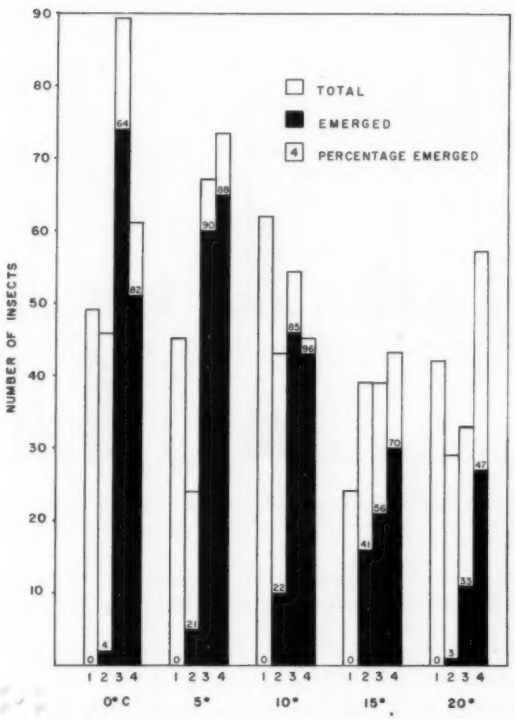


Fig. 20. Histogram of number of *C. oregonensis* larvae which were present in cone scales and number and percentage which emerged under different temperature and moisture conditions.

pupal development commenced in December and continued for about two months (Table VI). About two weeks after the insect has begun to shorten, the eye-buds which remain as a contiguous pair throughout larval development, begin to separate (Fig. 8b). At this stage they are visible from the dorsal aspect. They continue to separate and gradually move down to be visible from the ventral side of the insect (Fig. 8e). Pupation occurs soon after the eye-buds reach this location. At this time they are visible at the bases of the compound eyes (Fig. 7). They are almost certainly the "taches oculaires" described by Marchal (1897) in *Mayetiola destructor* Say. In early prepupal development the insect may remain in the U-shape characteristic of the third instar larva, but later assumes a straight position in the cocoon.

Pupa

Data in Table VI show that the pupal stage lasts about six weeks under field conditions. Development under controlled conditions varied slightly from that under outdoor temperatures. Insects kept at 5° C. pupated earlier than at the higher temperatures and outdoor temperatures, but adults did not emerge, so it was not possible to calculate the duration of the pupal stage. At 9° and 13° pupation and emergence commenced about one week earlier than under outdoor conditions but the duration of the stage was about the same.

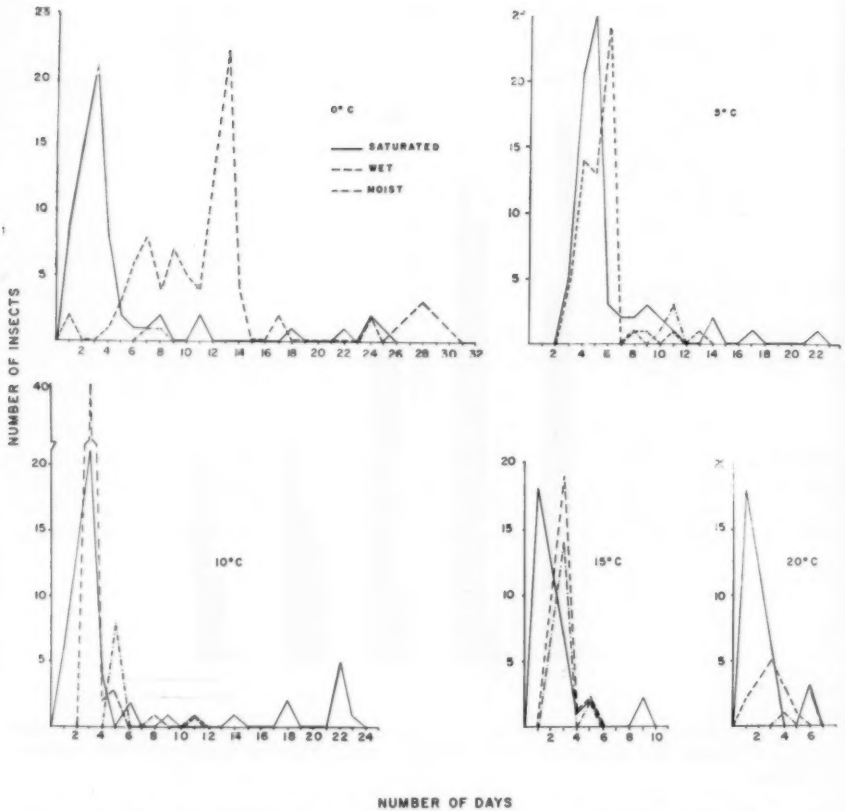


Fig. 21. Periods during which *C. oregonensis* larvae emerged from cone scales under different temperature and moisture conditions.

Diapause

Each year a portion of the population remains in diapause in the larval stage within the cocoon to emerge one or more years later. This characteristic is common to many species of cone and seed insects. In 1959, 23 (52%) of 44 cocoons from 1958 material reared in cages at Cowichan Lake contained larvae in diapause. In 1960, 36 (43%) larvae from 1959 material were in diapause. Johnson and Winjum (1960) recorded about 50 per cent of a population remaining in diapause in Washington.

Parasites

An ectoparasite, *Torymus* sp. and an endoparasite, *Platygaster* sp. nr. *americana* (Ashmead), have been observed.

Adults of *Torymus* were observed ovipositing in cones from June 18 to July 3 in 1958, and during the month of July in 1960. This chalcid deposits its egg (Fig. 13) in the chamber inhabited by the host larva, but it is never attached to or deposited inside the larva. As many as 13 eggs were observed in one chamber. The host larva is apparently paralysed or killed at the time the eggs are laid. Only one parasite develops on a host larva. It remains in the cavity

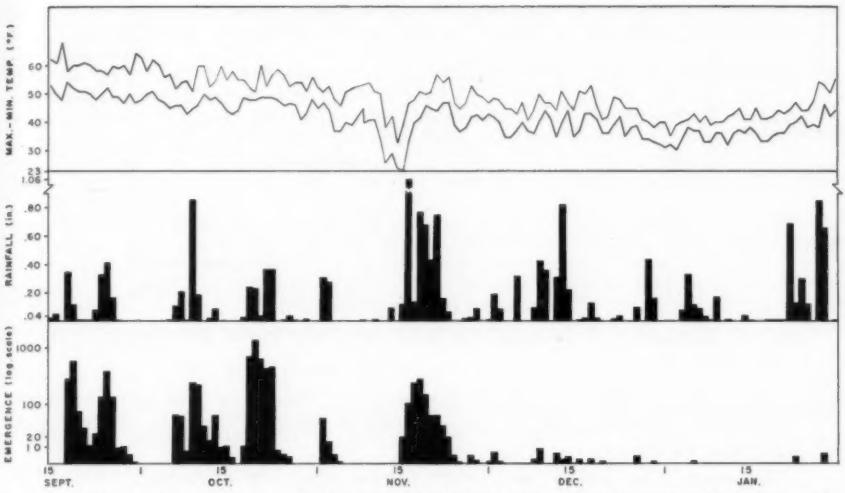


Fig. 22. Daily emergence of *C. oregonensis* larvae from infested cones with corresponding precipitation and temperature data, Victoria, B. C., 1959-60.

formed by the host to complete its development and emerge as an adult the following summer (Fig. 16). Of 1,011 host larvae examined in 1959, 48 (4.7%) were parasitized.

Adults of *Platygaster* sp. were observed in the field from May 5 to 22 in 1960. The young larva feeds endoparasitically (Fig. 14) but the host is not killed until some time after it has left the gall and spun a cocoon in the litter. The parasite remains within the last larval skin (Fig. 10) of the host in the cocoon until spring. Of 44 cocoons examined in 1959, 11 (25%) were parasitized by *Platygaster* sp.

Discussion

Douglas-fir cone crops may fluctuate tremendously from one year to the next. Since *C. oregonensis*, like all true cone insects, depends on the cone of its host as an oviposition site, and as a source of food and shelter during the larval feeding stage, it is affected by these fluctuations. It might be expected that the insect population would build up rapidly in good cone-crop years and be almost completely destroyed in poor years. Factors which protect the insect are its ability to locate and lay large numbers of eggs in the few available cones in a poor year, and its ability to remain in diapause. In some species of cone insects a high percentage of the population may remain in diapause during poor crop years. Under these conditions a good cone crop could be severely infested even when it follows a poor crop.

The insect is well adapted to its environment. Adults are active over a wide range of temperatures and so are able to deposit eggs even under relatively unfavourable weather conditions. In the autumn, larvae are able to survive for long periods in dry cones, and after leaving the cones, in water. Larvae concentrate in litter below the tree. This concentration of population probably facilitates mating when males and females emerge in the spring.

Summary

A cone midge, *Contarinia oregonensis* is one of a number of insect pests causing seed losses in Douglas fir. It is not as spectacular as some insects be-

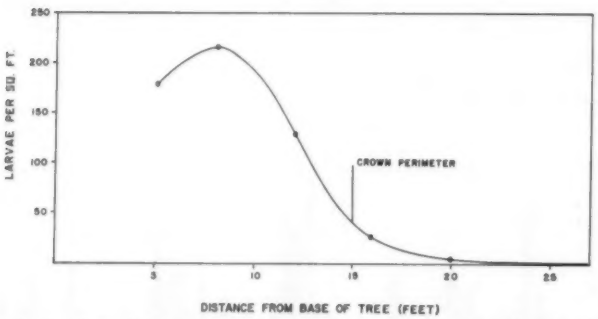


Fig. 23. Distribution of *C. oregonensis* larvae below tree crown after leaving cones.

cause its presence in the cone cannot be recognized from the cone exterior unless the infestation is severe. It has been reported in British Columbia, Washington, Oregon, and California.

The stages, life history, and habits of the insect are described. The adult deposits its eggs in newly opened female flowers in the spring. On hatching the larvae enter the scale tissue and cause a gall in the region of the ovules which prevents seed development, or causes the seed and scale to fuse. Larvae remain in the gall throughout the growth and development of the cone. When the cone reaches maturity in late summer the larvae are in the third and final instar. In late summer or autumn they leave the cone during wet weather. They drop to the ground and after selecting a site near the surface of the litter, spin cocoons in which to overwinter. The greatest concentration of insects is about half way between the base of the tree and the outer extremity of the crown. Only a small percentage of the insects fall outside the crown perimeter. Prepupal development takes place during the period from December to February. The pupal stage lasts about six weeks. When Douglas-fir flowers are bursting in early spring, adults emerge to lay their eggs.

A percentage of the population remains in diapause each summer.

Two species of parasites, *Torymus* sp. and *Platygaster* sp. nr. *americana* have been observed.

Acknowledgments

The author extends thanks to British Columbia Army Area Command, Department of National Defence, Vancouver, for permission to carry out experiments on Department of National Defence property; the Victoria City Weather Office, Department of Transport, Victoria, for weather data; the Experimental Farm, Department of Agriculture, for use of controlled temperature chambers; Dr. Lois K. Smith, and Dr. O. Peck, Ottawa, for identifying the parasites; Mr. D. Stirling, and Mr. W. G. Stickland, Victoria, for field and laboratory assistance; Mr. R. R. Lejeune, and Mr. J. M. Kinghorn, Forest Biology Laboratory, Victoria, and Mr. N. E. Johnson, Weyerhaeuser Timber Company, Centralia, Washington, for criticizing the manuscript; and Mr. A. Craigmyle, Victoria, for photographic work.

References

Felt, E. P. 1925. A key to gall midges. *New York State Mus. Bull.* No. 257: 71.

Foote, R. H. 1956. Gall midges associated with cones of western forest trees (Diptera: Itonididae). *Jour. Wash. Acad. Sci.* 46: 54.

Johnson, N. E. 1956. Project analysis. Douglas-fir cone and seed insects. Weyerhaeuser Timber Co. For. Res. Center, Centralia, Wash. 12 pp.

Johnson, N. E. 1958. Insect damage to the 1957 Douglas-fir seed crop on Weyerhaeuser Timber Company tree farms. Weyerhaeuser Timber Co. For. Res. Center, Centralia, Wash. 9 pp.

Johnson, N. E., and H. J. Heikkenen. 1958. Damage to the seed of Douglas-fir by the Douglas-fir cone midge. *For. Sci.* 4: 274-282.

Johnson, N. E., and J. K. Winjum. 1960. Douglas-fir cone and seed insect biological and control studies: progress in 1958, 1959. Weyerhaeuser Timber Co. For. Res. Note 22. 23 pp.

Keen, F. P. 1958. Cone and seed insects of western forest trees. *U.S.D.A. Tech. Bull.* 1169, 168 pp.

Koerber, T. W. 1960. Insects destructive to the Douglas-fir seed crop in California – a problem analysis. *U.S.D.A. Pac. S. W. For. and Range Exp. Sta. Berkeley, California Tech. Paper* 45, 36 pp.

Marchal, P. 1897. Les Cécidomyies des céréales et leurs parasites. *Ann. Soc. ent. France* 66: 1-105.

Miller, J. M. 1914. Insect damage to the cones and seeds of Pacific Coast conifers. *U.S.D.A. Bull.* 95, 7 pp.

Rudinsky, J. A. 1955. Douglas fir cone and seed insects. *Weyerhaeuser Timber Co. For. Res. Notes.* 6 pp.

Sen, P. 1939. On the function and development of the sternal spatula in the Cecidomyiidae or gall midges as exemplified by *Rhabdophaga saliciperda* Duf. *J. Morph.* 65: 1-15.

(Received January 24, 1961)

Notes on North American Chrysomelidae (Coleoptera)

By W. J. Brown
Entomology Research Institute, Research Branch
Canada Department of Agriculture, Ottawa, Ontario

Syneta Dejean

The name *Syneta* is usually attributed to Lacordaire, who was the first to publish it with a description (1845, Mém. Soc. Roy. Sci. Liége 3:226). It has also been attributed to Dejean, for it first appeared in the third edition of his Catalogue des Coléoptères (1837, p. 385) where it is ascribed to Eschscholtz. Barber and Bridwell (1940, Bull. Brooklyn Ent. Soc. 35:1-12) showed that such names were often validated by publication in the Dejean Catalog and that the chrysomelid names validated there should be attributed to Dejean, except those ascribed there to Chevrolat.

Edwards's treatment (1953, Wasmann J. Biol. 11:23-82) of *S. ferruginea* (Germ.) and *S. simplex* Lec. was admittedly unsatisfactory; he referred to each name several forms that required more study. The beetles that he referred to *ferruginea* now appear to belong to three entities, which are: (1) *extorris extorris* Brown, a form with dark males that is restricted to the southern Appalachians and depends on fir and spruce; (2) *extorris borealis* n. subsp., a form with pale males that occurs from Newfoundland to Ontario and New York and depends on fir and spruce; and (3) *ferruginea* (Germ.), a form that is dichromatic in the female and depends on Corylaceae. These forms differ morphologically only in color, and females cannot be identified by color, except the darkest of *extorris extorris* and those of the red phase of *ferruginea*.

The collection of Cornell University contains four males that are tentatively assigned and indicate regions in which special studies are desirable. Two of these, from Hillburn, southernmost New York, and Greenwood Lake, New Jersey, are colored like red females of *ferruginea* and are placed with that species. Edwards placed two similar males from Long Island and New Jersey with *ferruginea;* males of this species are not known from other regions. As noted

below, males of *extorris borealis* are numerous only in the southern parts of its range. Two of the Cornell males are from Skyland, Page Co., Virginia. They have the elytral costae elevated much more strongly than in other males but are tentatively assigned to *extorris extorris*, which they resemble in color. Prof. Robert Kral and Prof. A. B. Massey of Virginia Polytechnic Institute inform me that firs have a disjunct distribution in Virginia. They find them restricted to the southwestern counties Grayson, Smyth, Washington and Russell, and to the northern counties Page and Madison, where they are rare. Dr. E. H. Tryon of West Virginia University informs me that firs are apparently restricted in West Virginia to the central counties Randolph and Pocahontas. The collecting records of *extorris extorris* suggest that the beetle occurs only in the vicinity of firs; the presumption is that the Skyland males are from an isolated, relict population, and that *extorris extorris* and *extorris borealis* are strictly allopatric.

I am indebted to Dr. A. E. Brower of the Maine Forest Service and to Dr. Henry Dietrich of Cornell University for the privilege of studying the specimens of *Syneta* in their charge. To make the key that follows complete for the eastern forms of the genus, *S. pilosa* Brown (1940, Canadian Ent. 72: 164) is included.

Syneta extorris extorris Brown

Syneta extorris Brown, 1940, Canadian Ent. 72: 165 [type: Clingmans Dome, boundary of North Carolina and Tennessee, 6600 ft.].
Syneta ferruginea, Edwards, 1953, Wasmann J. Biol. 11: 51 (in part).

This form is restricted to higher elevations in the southern Appalachian Mountains. It has been taken only on the boundary of North Carolina and Tennessee at Clingmans Dome (6,200-6,600 ft.) and Indian Gap (5,200 ft.) and in the Black Mountains of North Carolina. As noted above, two males from Skyland, Va., resemble this form but are atypical. *S. extorris extorris* occurs abundantly on southern fir, *Abies Fraseri* (Pursh) Poir., and in very small numbers on red spruce, *Picea rubens* Sarg., which are its food-plants. Edwards's "mahogany variety" and "extorris variety" of *ferruginea* are this form, which has a peculiar habit in that the females emerge earlier than the males. In 1957 I collected on three dates from the same trees at Clingmans Dome and Indian Gap. On May 18 I took 28 females and no males, on May 20, 51 females and one male, on June 18, 35 females and 36 males.

Syneta extorris borealis, new subspecies

Syneta ferruginea, Horn, 1892, Trans. American Ent. Soc. 19: 4 (in part); Edwards, 1953, Wasmann J. Biol. 11: 51 (in part).

This form occurs from Newfoundland to Ontario and on the highest mountains of New York on balsam fir, *Abies balsamea* (L.) Mill., and, infrequently, on white and red spruce, *Picea glauca* (Moench) Voss and *P. rubens* Sarg., which are its food-plants. It extends south to Chalk River (46° N.) in Ontario and to Andover (44° 36′ N.) in Maine. In Canada males are very rare and are known only from Pleasant Bay, N.S., Duparquet, Que., and Biscotasing, Longlac, and Searchmont, Ont. Females, all presumably of this form, have been taken in numbers from the food-plants in all of the eastern provinces except Prince Edward Island. The New York series, which are not associated with food-plants, include 17 males from the mountains of Essex and Ulster Counties and 28 females from the same localities. The type series is restricted to specimens from Maine, because males are numerous there. Most specimens of Edwards's "typical variety" of *ferruginea* belong to this form, which is presumed to be only subspecifically distinct and which is characterized in the key that follows.

Holotype.— ♂, Portage, Aroostook Co., Maine, May 28, 1952, beaten from fir; No. 7243 in the Canadian National Collection.

Paratypes.—Maine: 23 ♂, 14 ♀, same locality and food-plant, May 2 to June 17; 2 ♂, 1 ♀, Eagle Lake, Aroostook Co., June 14, 1952, ex fir; 1 ♂, 1 ♀, Clayton Lake, Aroostook Co., June 30, 1953, ex fir; 3 ♂, Ashland, Aroostook Co., June 4, 1951, ex fir; 2 ♂, 1 ♀, St. Francis, Aroostook Co., June 16 and 22; 2 ♂, 1 ♀, Allagash, Aroostook Co., June 5, 1959, ex fir; 6 ♂, 3 ♀, Grafton, Oxford Co., June 5 to 24, of which 3 are from fir; 1 ♂, 2 ♀, Andover, Oxford Co., June 24, 1952, ex fir; 14 ♂, 11 ♀, Rangeley, Franklin Co., June 5 to July 17, of which 16 are from fir and 1 is from spruce; 2 ♂, Stratton, Franklin Co., April 27, ex fir; 5 ♂, 1 ♀, Eustis, Franklin Co., June 13 to July 18, of which 1 is from fir and 2 are from spruce; 3 ♂, Seboomook, Somerset Co., July 10, 1947, ex fir; 3 ♂, Jackman, Somerset Co., June 6, ex fir; 5 ♂, 3 ♀, Greenville, Piscataquis Co., May 26 to June 13, of which 6 are from fir.

Paratypes are deposited in the Canadian National Collection and in the collections of the U.S. National Museum, Cornell University, and the Forest Service of Maine.

Syneta ferruginea (Germar)

Donacia ferruginea Germar, 1811, Neue Schrift. Halle Naturf. Gesell. 1(6): 34 [type: North America].

Syneta ferruginea, Lacordaire, 1845, Mém. Soc. Roy. Sci. Liége 3: 232; Crotch, 1873, Proc. Acad. Nat. Sci. Philadelphia 25: 24 (in part); Horn, 1892, Trans. American Ent. Soc. 19: 4 (in part); Blatchley, 1910, Coleop. Indiana, p. 1110; Edwards, 1953, Wasmann J. Biol. 11: 51 (in part).

Orsodacne tripla Say, 1826, J. Acad. Nat. Sci. Philadelphia 5: 281 [no locality given, but *Crioceris asparagi* Melsheimer of Pennsylvania is listed as a synonym]; LeConte, 1859, Complete Writings of T. Say 2, p. 337.

Syneta tripla, Lacordaire, 1845, Mém. Soc. Roy. Sci. Liége 3: 233.

Orsodachna costata Newman, 1838, Ent. Mag. 5: 391 [type: Trenton Falls (near Utica), New York].

Syneta costata, Lacordaire, 1845, Mém. Soc. Roy. Sci. Liége 3: 233.

Syneta rubicunda Lacordaire, 1845, loc. cit., p. 230 [type: North America].

S. ferruginea lacks males throughout most of its range. It occurs from Newfoundland to Manitoba and southward at least to Pennsylvania and Indiana. It feeds without apparent preference on *Corylus* spp., *Betula* spp., *Ostrya virginiana* (Mill.) K. Koch, and *Alnus rugosa* (DuRoi) Spreng. Thus it feeds on all genera of Corylaceae except possibly *Carpinus*, its relation to which is unknown. It occurs in two color phases. The more common form is dull, pale yellow except the head and pronotum, which are reddish-yellow. The other form is dull, medium red above; the underside is pale red, and the legs are yellow or reddish-yellow. These forms occur together and, except for color, are similar in every respect. As noted above, four males that agree in color with red females of *ferruginea* are known from southernmost New York and New Jersey; apparently they are properly referred to *ferruginea*. Edwards's "rufous-sutured" and "rufous" varieties and some specimens of his "typical" variety belong to *ferruginea*.

Judging by the descriptions, the types of *ferruginea* and *tripla* were specimens of the red form, the color of which is distinctive. I have seen the types of *rubicunda* and *costata*. The former is a female of the red form. The latter is a yellow female and is referred to *ferruginea* because it was taken near Utica, New York. Because *extorris borealis* is not known in Ontario south of 46° N., it is presumed to be restricted in New York to the Adirondack and Catskill Mountains.

Key to the Eastern Forms of *Syneta* Dejean

1. Elytra distinctly pubescent, at least when viewed obliquely; the length of the hair of each puncture twice as great as the diameter of the puncture. Food-plants: *Abies* and *Picea*. Occurring from Newfoundland and Maine to Yukon Territory and northern California ..... *pilosa* Brown
   Elytra with few or no distinct hairs, usually apparently glabrous; the length of the hair of each puncture equal to the diameter of the puncture 2
2. Males (apical ventral segment not excavated) 3
   Females (apical ventral segment with a large, deep excavation) 5
3. Entirely red or reddish-yellow above, the elytral suture not darker; antennae entirely red; legs and underside entirely reddish-yellow. Males known only from New Jersey and southernmost New York that presumably feed on Corylaceae and presumably are ..... *ferruginea* (Germ.)
   Elytra dull yellow or brown; when pale, with the suture darker than the disc; antennae, legs, and underside bicolored or at least with distinctly infuscate areas. Food plants: *Abies* and, infrequently, *Picea* 4
4. Darker; usually dark or very dark brown above, the elytra not as dark as the body beneath and frequently less dark than the anterior parts; antennal fossae, clypeus, labrum, bases of the femora, trochanters, and apices of the coxae pale yellow; pronotum often reddish-brown at base and apex. Palest specimens with the elytra, except the sutural intervals, medium brown; head and pronotum largely reddish-brown; tibiae and tarsi brown; segments two and three of each antenna yellow. Occurring at high altitudes in North Carolina, Tennessee, and Virginia ..... *extorris extorris* Brown
   Paler; largely dull yellow above; the elytra paler than the body beneath and usually paler than the anterior parts; the head and legs with pale parts as in *extorris extorris* but with those of the femora more extensive; usually with middle third of the pronotum and much of the head pale brownish-red; underside and darker parts of the legs varying from brownish-yellow to medium brown; each antenna with three or more subbasal segments pale. Occurring from Newfoundland to Ontario and New York ..... *extorris borealis*, new subspecies
5. Usually darker; elytra varying from pale yellow to pale brown, the suture usually reddish-brown; head except apically and middle third of pronotum reddish-brown; underside, apical parts of the femora, tibiae, and tarsi usually reddish-brown, the legs sometimes entirely pale; antennae usually dark except basally, rarely entirely pale; the palest specimens as in *extorris borealis*. Food-plants: *Abies* and, infrequently, *Picea*. Occurring at high altitudes in North Carolina, Tennessee, and Virginia ..... *extorris extorris* Brown
   Paler, usually entirely pale; elytra pale yellow, the suture reddish; head, pronotum, antennae, underside, and legs usually pale reddish-yellow, the metasternum sometimes darker; darkest specimens with the elytral suture and with parts of the head, pronotum, antennae, underside, and legs reddish-brown as in many specimens of *extorris extorris*. Food-plants: *Abies* and, infrequently, *Picea*. Occurring from Newfoundland to Ontario and New York ..... *extorris borealis*, new subspecies
   Color as in the average and palest specimens of *extorris borealis*, or with the entire upper surface except the anterior portion of the head dull, medium red. Food-plants: *Almus*, *Corylus*, *Betula*, and *Ostrya*. Occurring from Newfoundland to Manitoba and southward ..... *ferruginea* (Germ.)

Anomoea spp.

The species of this genus are very poorly known, but some of the synonymy proposed by Monrós is obviously erroneous. *A. laticlavia* (Forster) occurs from southwestern Manitoba to Quebec and Gadsen Co., northwestern Florida. Females with the elytra largely blackish are frequent in the Southeast but are not found in Canada, and, according to Schaeffer (1933, J. New York Ent. Soc. 41: 314), the dark markings are reduced in specimens from central Kansas; otherwise the series show no geographic variation. Monrós (1954, Psyche 60: 148 [1953]) listed the Mexican species *rufifrons* (Lac.) and *villosa* (Jacoby) as synonyms of *laticlavia*. This cannot be correct, for *laticlavia* is not known in the United States from the regions south of Kansas. Moreover, *villosa* is a very dark species that differs from *mutabilis* only in having the dorsum pubescent

according to Jacoby (1888, Biologia Cent.-Americana 6(1), Suppl., p. 67). Monrós (1954, Proc. Ent. Soc. Washington 56: 23) also listed *crassicornis* Schaeff. as a color form and synonym of *laticlavia*. The former differs, as stated by Schaeffer (op. cit., p. 313), in having the antennal segments distinctly wider than in *laticlavia*. The two species also differ in distribution. *C. crassicornis* occurs from Pinellas Co. and Palm Beach Co. to Dade Co., Florida, and is apparently restricted to the southern part of that state.

Anomoea högei (Jacoby). This species, which has been known only from Mexico and Texas, is represented in the Canadian National Collection by 11 specimens, all females, from Williamsville, southeastern Missouri. They are entirely pale except the scutellum in several, antennal segments four or five to 11, the meso- and metathorax, abdomen, anterior tibiae, and all tarsi; the middle tibiae are infuscate in two specimens.

Chlamisus Rafinesque

In *Chlamisus prosternalis* (Schaeff.), *scabripennis* (Schaeff.), and *subelatus* (Schaeff.), the elytra are not contiguous behind the scutellum and the metascutellum is visible. Because of this, Monrós (1954, Proc. Ent. Soc. Washington 56: 24) suggested that they be transferred to *Diplacaspis* Jacobson. Several authors have followed Baly (1879, J. Linnean Soc. London 14: 343) and have placed *memnonius* (Lac.) and *moestificus* (Lac.) in *Diplacaspis* for the same reason. Monrós also noted differences between the larva of *D. paradoxa* (Lac.), the type species of *Diplacaspis*, and a "typical *Chlamisus* larva". *Chlamisus*, as now constituted, is highly heterogeneous, and it is impossible to evaluate larval characters at this time. The scutellar character is not of generic value. According to Jacoby (1881, Biologia Cent.-Americana, Coleoptera 6(1), p. 75) and Linell (1898, Proc. U.S. Nat. Mus. 20: 477), the metascutellum may be either visible or concealed in *memnonius*. Jacoby also noted that it is "sometimes almost indistinct" in *moestificus*. Schaeffer (1919, J. New York Ent. Soc. 27: 325) commented on its variation in *moestificus* (= *confusus* Schaeff.) and stated that, as a generic character, it is "valueless". I found (1943, Canadian Ent. 75: 129) that it is sometimes visible in *bebbianae* (Brown), one of the sibling species of the *plicatus* complex.

Chlamisus spp.

Chlamisus plicatus (Fab.). The cotypes of this species were taken in "Carolina" by Bosc, who probably collected them near Charleston, S.C. The species was redescribed by Coquebert (1804, Illustratio iconographica insectorum, decas 3, p. 129, Pl. 29, Fig. 8) and by Olivier (1808, Entomologie 6, p. 876, Pl. 1, Fig. 3b), probably from type material. Their figures indicate that the species measures about 4.5 mm. It is thus larger than any species of the general region except the one I tentatively, and evidently correctly, identified as *plicatus* in 1943 (Canadian Ent. 75: 127). This species occurs very abundantly on the subgenus *Eubatus* Focke, genus *Rubus* L., in south-central South Carolina.

Chlamisus alni (Brown). This species has been known only from eastern Ontario and western Quebec, where it breeds on *Alnus rugosa* (du Roi) Spreng. (= *incana* of American authors). It occurs also at Pine Mountain (1,400 feet), Rabun Co., Georgia, on *Alnus serrulata* (Ait.) Willd. Like all Canadian specimens, all of the 18 from Pine Mountain are females.

Chlamisus nodulosus (Blatchley)

Chlamys nodulosa Blatchley, 1913, Canadian Ent. 45: 22 [lectotype and cotypes: Sanford and (cotypes) Ormond, Florida]; Blatchley, 1930, Blatchleyana, p. 37.

This species is common on oak in Florida. It is dark coppery and measures from 2.4 to 3.2 mm.; Blatchley gave the size incorrectly. The summit of the

pronotum bears two conical tubercles that are separated by a broad, U-shaped space. As Blatchley noted, it is difficult to separate and define *Chlamisus* and *Exema*, but *nodulosus* is a true *Chlamisus;* the fifth segment of each antenna is strongly transverse and similar to the following segments. Authors have followed Leng (1918, J. New York Ent. Soc. 26: 208) in considering *nodulosus* a synonym of *Exema gibber* (Fab.). The type of *gibber* was taken in "Carolina" by Bosc. As *gibber* cannot be critically identified, at least until the fauna of southeastern South Carolina has been studied, the name *nodulosus* should be retained for the Floridian species.

***Chlamisus azaleae*, new species**

Belonging to the *plicatus* complex (Brown, 1943, Canadian Ent. 75: 119-131). Length of males 3.0 mm., of females 3.4 to 3.6 mm. Copper-colored as in *comptoniae* (Brown) except three of the eight specimens, which have a slightly greenish cast and are therefore brassy; antennae, labrum, and a spot within the emargination of each eye yellow, the antennae not infuscate. Body shining throughout but with only the pronotum, which lacks microsculpture, highly polished.

Head and pronotum exactly as in *comptoniae*. Pronotum with the gibbosity, in cephalic aspect, relatively wide; the strigose sculpture relatively coarse; the sides with sparse, moderately coarse punctures that are often evident only in certain lights. Elytral sculpture of the usual type, the tubercles better developed and the strigulose sculpture finer than in *comptoniae*.

Prosternal plate goblet-shaped, the anterior portion relatively wider in females than in males; otherwise not varying sexually. Metasternum and its episterna with very large, shallow, dense punctures, which are usually confluent in part on the episterna; first abdominal segment with similar punctures which are sometimes less well defined, externally roughened by more or less obsolete foveae. Apical ventral segment coarsely, more or less confluently punctate; pygidium with coarse, close punctures, not vermiculate; the sculpture of all these parts much as in *comptoniae*.

Male: Each anterior tibia on the inner side at apex with two small, spur-like processes; these separated by a V-shaped notch. Each middle tibia with a single similar process. Copulatory organ apically as in *comptoniae*, the apex acutely pointed but strongly deflexed so that the organ appears broadly rounded or subtruncate in dorsal aspect. Flagellum more elongate than in any other species, from 82 to 92 per cent as long as the portion of the organ distad to the submedian constriction; basal orifice of the flagellum occupying from 27 to 32 per cent of the flagellar length.

Female: Each anterior tibia with a single minute process on the inner side at apex. Each middle tibia with a similar process in some specimens but with the process usually obsolete and not or scarcely evident even in properly mounted specimens. Apical ventral segment with a large, median concavity as in allied species.

Food-plant: an azalea (subgenus *Anthodendron* Endl. of *Rhododendron* L.; *Azalea* of many authors).

Holotype.— ♂, Highlands, North Carolina, 3,800 feet, June 12, 1957 (W. J. Brown), swept from azalea; No. 6917 in the Canadian National Collection, Ottawa.

Allotype.— ♀, same data, but collected June 13, 1957.

Paratypes.—2 ♂, 3 ♀, same locality and collector, the males swept from azalea on June 26 and 29, 1957, the females reared from larvae taken from azalea; 1 ♀, Walhalla, South Carolina, 1957 (W. J. Brown), reared from larva found on azalea.

All specimens from Highlands are from a single colony. Because of its small size, coppery color, and sculpture, this species is readily confused with *comptoniae*. It is most readily separated from *comptoniae* by the elongate flagellum of the male organ and by the minute, but quite evident, spur-like process of each front tibia of the female.

Colaspis Fabricius

Colaspis Fabricius, 1801, Syst. Eleutheratorum 1: 411 [27 species including *C. flavicornis* Fabricius, which was designated type species of the genus by Latreille, 1810, Considérations Générales sur l'Ordre Naturel des Animaux, p. 432].

Maecolaspis Bechyné, 1950, Mitt. Münchner Ent. Ges. 40: 275 [type species: *Colaspis occidentalis* (Linnaeus) (= *Colaspis flavicornis* Fabricius), designated by Bechyné, loc. cit.]. *New synonymy.*

Bechyné incorrectly considered *Colaspis testacea* Fabricius the type species of *Colaspis* and erected the genus *Maecolaspis* for the species listed in *Colaspis* in recent catalogs. He incorrectly synonymized *Metaxyonycha* Chevrolat with *Colaspis*. The nomenclature of the Junk catalog and of other recent catalogs is correct.

Labidomera mimica, new species

Length 10.4 to 10.8 mm. Except the elytra, entirely dark blue. The elytra of the two males entirely pale reddish-yellow except the suture, which is very narrowly dark on the apical third or two-thirds; this narrow stripe not widened at the apex. The single female with the elytra similarly pale and with a dark suture but spotted with black as in most specimens of *clivicollis rogersii* (Lec.); i.e., each elytron with a large humeral spot; a small, median, subbasal spot; a large, slightly transverse sutural spot immediately before the middle; a median spot of moderate size immediately behind the middle; a small, sublateral spot just behind the middle; and a small, sublateral spot near the apex. Elytral punctures considerably finer and sparser than in *clivicollis* (Kby.) and its subspecies *rogersii;* all other characters as in those forms.

Holotype, ♂, and 1 ♂ and 1 ♀ *paratype*: White Rose Canyon, Jeff Davis Co., Texas; June 18, 1947 (A. T. McClay); in the collection of the University of California, Davis, and (♂ paratype, No. 7577) in the Canadian National Collection.

The unspotted specimens of *mimica* resemble very closely specimens of the Mexican species *suturella* Chev. and can be separated only by the form of the sutural stripe and by the male characters. In *suturella* the stripe extends to the base of the elytra and is widened immediately before the apex to widely darken the apical elytral angles; each anterior femur of the male bears two instead of one subapical tooth; each anterior tibia of the male is abruptly rather than gradually widened at middle; and the male genital organ is slightly sinuate, rather than arcuately convex, on each side before the pointed apex. The spotted specimen of *mimica* differs only in elytral sculpture and size from specimens of *clivicollis rogersii;* the latter form measures from 8.0 to 9.3 mm. and occurs from Winnipeg and Brandon, Manitoba, to Brownsville, southernmost Texas.

I am indebted to Mr. A. T. McClay, curator of the collection at Davis, for the specimens of *mimica*.

Leptinotarsa texana Schaeffer, new status

Leptinotarsa defecta, Linell, 1896, J. New York Ent. Soc. 4: 196.

Leptinotarsa decemlineata texana Schaeffer, 1906, Brooklyn Mus. Arts and Sci., Sci. Bull. 1: 239 [cotypes: Brownsville, Texas].

Leptinotarsa defecta texana, Leng, 1920, Cat. Coleop. America, p. 295.

This form, which has been associated with *decemlineata* (Say) and *defecta* (Stål) as noted above, is well-characterized as was noted by Linell and Schaeffer

and is obviously specifically distinct. Schaeffer found both *texana* and *defecta* at Brownsville, Tex., and the collection of Cornell University contains 13 specimens of *texana* and 11 of *decemlineata* from Kingsville, Kleberg Co., southernmost Texas. *L. texana* does not intergrade with either of the others.

Chrysomela mainensis mainensis Bechyné, new status

Chrysomela interrupta mainensis Bechyné, 1954, Ent. Arbeiten aus Mus. G. Frey 5: 670 [cotypes: Dryden, Maine, and La Trappe, Que.].

Chrysomela alnicola alnicola Brown, 1956, Canadian Ent. 88, Suppl. 3, p. 27. [type and paratypes: Constance Bay, Ont.). *New synonymy.*

The cotypes of *mainensis*, more than 50 specimens, are described as having seven discrete dark spots on each elytron. The form that I described as *alnicola alnicola* is the only form of the *interrupta* complex in eastern Canada and adjacent regions that has the spots consistently reduced to that degree. As noted with the description of *alnicola alnicola*, this species and *interrupta* Fab. are quite distinct.

Chrysomela knabi hesperia, new subspecies

Chrysomela knabi Brown, 1956, Canadian Ent. 88, Suppl. 3, p. 34 (in part).

Restricted to the Great Plains; differing from the more eastern *knabi knabi* Brown in having the dark markings of the elytra reduced.

The type series of 89 specimens including 31 of the quadrimaculate dimorph, i.e., 31 with only a median pair of spots on each elytron; the 58 specimens of the fully maculate form including 25 with all seven spots of each elytron discrete, 32 with only the two postmedian spots joined together, one with these spots joined and with the two basal spots joined to produce a single U-shaped spot, and no specimens with the postmedian spots joined to the subapical spot.

Holotype, ♂, and 88 *paratypes*: Lethbridge, Alberta, 1956, on *Salix;* No. 7576 in the Canadian National Collection.

A series of 33 specimens taken 120 miles east of Lethbridge at Irvine, Alta., includes six of the quadrimaculate form, 10 with all seven spots of each elytron free, 16 with only the two postmedian spots joined together, one with these joined and with the two basal spots joined to produce a single U-shaped spot, and none with the postmedian spots joined to the subapical spot.

The elytral maculation of *knabi* varies clinally. Series from southernmost Ontario, eastern Tennessee, and more eastern regions agree well with one another. They are heavily maculate and include very few or no individuals of the quadrimaculate form. Of the 150 specimens of the type series of *knabi*, from Point Pelee, Ont., 90 per cent have the basal spots joined together, 83 per cent have the postmedian spots fused and joined with the subapical spot, and only one is quadrimaculate. The maculation gradually becomes less heavy westward to eastern Kansas. Of 97 specimens from Lawrence, Kans., 46 per cent have the basal spots joined, and 44 per cent have the postmedian spots fused and joined to the subapical spot; the quadrimaculate form has not been found in eastern Kansas. None of the Point Pelee series and only three of the Lawrence series are as lightly maculate as average specimens of *knabi hesperia.* West of Lawrence the cline steepens suddenly and greatly and then levels off; series from western Kansas resemble the others from the Great Plains. *C. knabi hesperia* is known to occur from Alberta to Manitoba and western Oklahoma.

I am indebted to Dr. G. A. Hobbs, Canada Agriculture Research Laboratory, Lethbridge, Alta., for the type series and to Mr. A. R. Brooks, Canada Agriculture Research Laboratory, Saskatoon, Sask., for the Irvine series of *hesperia.*

Gonioctena nivosa arctica Mann. and *G. nivosa alberta* Brown new combinations

I have already noted (1942, Canadian Ent. 74: 100) the difficulty of relating properly *G. nivosa* (Suffr.) of the Alps, *G. affinis* (Gyll.) of northern Europe, *G. arctica* Mann. of Alaska and northwestern Canada, and *G. arctica alberta* Brown (1952, Canadian Ent. 84: 340) of the Rocky Mountains. Holdhaus and Lindroth (1939, Ann. Naturhist. Mus. Wien 50: 208), like some earlier authors, associated all of these as *affinis*. The forms are very similar, but there are differences. Holdhaus and Lindroth noted that the tibiae of *nivosa* are nearly always partly pale and that those of *affinis* are nearly always entirely dark. The tibiae are largely pale in the American forms. In *affinis*, of which I have seen many Scandinavian specimens, the prothorax is always entirely dark. In *alberta* the prothorax is entirely dark or only narrowly rufescent on the sides in 18 of our 19 specimens. In *arctica* the prothorax is broadly margined with pale laterally or both laterally and apically in seventy-five per cent or more of the specimens, depending on locality, and the humeral and subsutural spots of the elytra are usually better developed than in *affinis*. As noted in its description, *alberta* differs in sculpture.

In view of the distribution of these forms and the differences they show, it is probably best to treat them as subspecies of one species. The Zoological Museum of Helsingfors has two specimens labelled "Shigansk, Lena infer., B. Poppius", which were identified as *affinis arctica* by D. Ogloblin. They have five black spots on each elytron; they have the prothorax very widely margined with pale laterally and anteriorly and have the tibiae almost entirely pale. They have the color and genitalic characters of *arctica* and extend the range of that form into central Siberia.

As *Chrysomela affinis* Gyllenhal, 1808, is preoccupied by *C. affinis* Fabricius, 1801, *C. nivosa* Suffrian, 1851, is the oldest available name.

Gonioctena occidentalis (Brown)

Phytodecta occidentalis Brown, 1942, Canadian Ent. 74: 104.

The type series of this species consists of 29 specimens from British Columbia and western Alberta. In all of these the pronotum is bicolored, and the elytra are red and more or less spotted with black. Twenty-five per cent of 205 specimens from Sunwapta Pass (6,700 feet), Banff National Park, Alberta, are darker. They have the elytra dark reddish-brown, with the spots obscure or lacking, or entirely blackish. In some of them the entire body is blackish except the antennae, clypeus, anterior angles of the prothorax, tibiae, and tarsi, which are rufescent. The species occurs also at Kluane, southwestern Yukon Territory.

Phratora interstitialis Mannerheim

Phratora interstitialis Mannerheim, 1853, Bull. Soc. Imp. Nat. Moscou 26: 259.
Phyllodecta aklaviki Carr, 1932, Canadian Ent. 64: 192. New synonymy.
Phratora aklaviki, Brown, 1951, Canadian Ent. 83: 123.

This species has been known only from the original description. Its unique type was taken "ad fl. Kwichpakh", which is the Yukon River according to Mannerheim's map (op. cit., Pl. 2). The type is not in the Mannerheim collection at Helsingfors. The collection of the U.S. National Museum contains 14 specimens that were taken on the lower Yukon between Andreafski (163° 46' W.) and Holy Cross (159° 46' W.). These agree with the description of *interstitialis* and must be referred to that species. They agree also with the type of *aklaviki*, which was taken near Aklavik in the Mackenzie Delta. The species occurs also at Beaver and Circle, east-central Alaska, Hootalinqua and Big Salmon,

southwestern Yukon Territory, and, as I previously noted, east to Great Slave Lake and east-central British Columbia. Mannerheim noted particularly the characteristic elytral sculpture of the species. He noted also a large, oblique fovea on each side of the pronotum of his type and suspected that the foveae were fortuitous. Fortuitous foveae occur commonly on the pronotum of the species. They are present on one or both sides in half of the Yukon River specimens.

Phratora kenaiensis Brown, new status

Phratora purpurea kenaiensis Brown, 1952, Canadian Ent. 84: 339.

P. kenaiensis differs from *purpurea* Brown only in the size and color characters that are noted below in the description of *P. californica* n. sp. Because of this, *kenaiensis* was presumed to be an Alaskan subspecies of *purpurea*, which occurs from Nova Scotia and Massachusetts to southern British Columbia and Yukon Territory without varying geographically. The relationship of these forms is similar to the relationship of *hudsonia* Brown to *frosti remissa* Brown, which differ morphologically only in size and color but appear to be specifically distinct because of their distributions and food-plants. It seems better, therefore, to consider *kenaiensis* and *purpurea* specifically distinct.

Phratora californica, new species

Length 4.7 to 5.0 mm. Deep green or bluish-green above, depending on the light. Other characters as in *purpurea* Brown. Food-plant unknown.

Holotype, ♂, and 1 ♂ and 1 ♀ *paratype*: Dyerville, Humboldt Co., California; May 20, 1935 (E. A. Drews); in the collection of the University of California, Davis, and (♂ paratype, No. 6295) in the Canadian National Collection.

This species differs only in size and color from *purpurea* Brown (1951, Canadian Ent. 83: 124), which measures from 3.7 to 4.7 mm. and is purple or reddish-purple above. It agrees in size with *kenaiensis* Brown (1952, Canadian Ent. 84: 339), which is blackish and shows feeble green or bronze reflections above. The punctures of the elytral striae are relatively fine in *californica;* they are similar to those of *purpurea* and are finer than those of *kenaiensis*.

I am indebted to Mr. A. T. McClay, curator of the collection at Davis, for the specimens of *californica*.

Phratora frosti remissa Brown

Phratora frosti remissa Brown, 1951, Canadian Ent. 83: 129.

This subspecies, which has been known only from Manitoba, Alberta, and Wyoming, occurs from Labrador and the Gaspé Peninsula to western Alaska and Colorado. The additional localities are: Cartwright, Labrador; Gaspé and Cap Chat, Que.; Hudson Bay and Prince Albert, Sask.; Black Hills, S. Dak.; Rocky Mountain National Park, Colo.; King Salmon (Naknek River) and Naknek (base of the Alaska Peninsula), Alaska.

All specimens from the additional localities are quite typical. None approach or resemble *frosti frosti* Brown, which differs only in color and which is known only from Nova Scotia.

Phratora hudsonia Brown

Phratora hudsonia Brown, 1951, Canadian Ent. 83: 128.

This species, which has been known only from Great Slave Lake, occurs from the eastern coast of Hudson Bay to southwestern Manitoba and western Alaska. The additional localities are: Great Whale River, Que.; Grandview and Churchill, Man.; Selwyn Lake (60° 11′ N., 104° 25′ W.), Salmita Mines (64°

05′ N., 111° 15′ W.), and Fort McPherson, N.W.T.; Forty Mile, Fort Selkirk, Dawson, and Kirkman Creek, Y.T.; Fort Yukon, Eagle, and Moose Pass (Kenai Peninsula), and also Stuyahok, Anvik, and intermediate points on the Yukon River (approximately 62° 30′ N., 160° W.), Alaska.

Only species of *Salix* and *Populus* have been reported as food-plants for *Phratora*, but *P. hudsonia* depends on *Betula*. S. D. Hicks of the Entomology Research Institute, Ottawa, found *hudsonia* in large numbers on *B. papyrifera* Marsh. at Fort McPherson. Officers of the Canadian Forest Insect Survey reared adults of *hudsonia* from larvae found on *B. papyrifera* at Selwyn Lake and on *Betula* sp. at Grandview.

Summary

Described as new are: *Syneta extorris borealis*, which occurs from Newfoundland to Ontario and New York; *Chlamisus azaleae* from North and South Carolina; *Labidomera mimica* from southwestern Texas; *Phratora californica* from Humboldt Co., California; and *Chrysomela knabi hesperia* from the Great Plains. Placed in synonymy are: *Maecolaspis* Bechyné, under *Colaspis* Fab.; *Phratora aklaviki* Carr, under *P. interstitialis* Mann.; and *Chrysomela alnicola alnicola* Brown, under *C. mainensis mainensis* Bechyné (= *C. interrupta mainensis* Bechyné). Removed from synonymy are *Syneta extorris* Brown, *Chlamisus nodulosus* (Blatch.), *Amomoea rufifrons* (Lac.), *A. villosa* (Jacoby), *A. crassicornis* Schaeff., and the genus *Metaxyonycha* Chev. *Chlamisus prosternalis* (Schaeff.), *C. scabripennis* (Schaeff.), and *C. subelatus* (Schaeff.) are removed from *Diplacaspis* Jacobson and returned to *Chlamisus* Raf. Included are notes on the status, distribution, and food-plants of forms in these genera except *Colaspis* and in *Leptinotarsa* and *Gonioctena*.

(Received June 15, 1961)

Control of Toadflax by *Brachypterolus pulicarius* (L.) (Coleoptera: Nitidulidae) and *Gymnaetron antirrhini* (Payk.) (Coleoptera: Curculionidae) in Canada

By P. Harris

Entomology Research Institute for Biological Control, Research Branch
Canada Department of Agriculture, Belleville, Ontario

The principal insects that attack toadflax (*Linaria vulgaris* Mill.) in Canada are *Brachypterolus pulicarius* (L.), a flower-eating nitidulid, and *Gymnaetron antirrhini* (Payk.), a seed-eating weevil. *B. pulicarius* was found in 1953 in all provinces of Canada but *G. antirrhini* was apparently absent from Saskatchewan and Alberta, the two provinces where the spread of toadflax was causing alarm. Thus the seriousness of the toadflax seemed to be related to the absence of *G. antirrhini*. In an attempt to correct this situation Smith (1959) collected 4,000 adult *G. antirrhini* and released them in mid-July, 1957, at Marsden, Saskatchewan, and Codesa, Alberta. However, it now appears that the rapid spread of toadflax occurred in the absence of *B. pulicarius* and that this beetle is more valuable than first thought. This paper discusses the role of *B. pulicarius* and the results of introducing *G. antirrhini*.

B. pulicarius

B. pulicarius adults emerge in May in Southern Ontario and feed on the young toadflax stems, causing stooling. They pair in early June and lay in the

flower buds. The young larvae feed chiefly on the anthers and ovaries in the buds and flowers; the older larvae also feed on the maturing seeds. The larvae move freely from one flower to the next and each destroys many in the course of its development. They are responsible for an almost complete destruction of flowers in the early summer, but in early August the adults disappear, except for a rare individual, and by mid-August all but the occasional larva has completed feeding and entered the soil for pupation, as indicated by Smith (1959). In contrast, on the prairies *B. pulicarius* continue to attack toadflax through the summer and fall until freeze-up. For example, both larvae and adults were abundant on 10 September, 1960, at Marsden, Saskatchewan, and a sample of 12 toadflax stems taken on 1 October, 1957, yielded 8 adults and 9 larvae (Smith, unpublished data). This persistence of *B. pulicarius* until winter results in most of the toadflax flowers being destroyed without developing seed. Thus, on a sample of 12 stems from Marsden, collected 22 August, 1957, there were 26 flowers, 10 seed capsules (3 containing *G. antirrhini* larvae) and 380 buds and flowers that had been destroyed by *B. pulicarius* (Smith, unpublished data). No satisfactory explanation for the difference in the life cycle in Southern Ontario and the prairies has been found.

The recent colonization of toadflax in Saskatchewan and Alberta by *B. pulicarius* has to be largely deduced from circumstantial evidence as there were few direct surveys made on the beetle itself. Toadflax, a weed of Eurasian origin, has been present on the prairies for several decades, but it was not until the late 1940's that the acreage occupied by the weed and its rate of spread caused serious alarm. Surveys made to determine its extent in 78 Saskatchewan municipalities (approximately a third of the settled area of the province) indicated that 134,327 acres were infested (Coupland *et al.*, 1954). A resurvey of one municipality two years later showed that the average number of patches of toadflax had increased from 5.1 to 9.2 per quarter section, or almost doubled (Frankton, 1951). Likewise Zilke and Coupland (1954) found that a patch 0.71 square meters increased 418 per cent in a single season and a patch originally one acre in extent expanded to 85 acres in 5 years. The reason for this rapid rate of spread is the prolific seed production: in 1952 estimated to average 5,584 seeds per flowering stem in Saskatchewan (Zilke and Coupland, 1954). They also found that cultivation only served to increase further the density of the weed, and Beck (1954) reported that the acreage infested by toadflax had increased considerably over the past few years despite heavy expenditure for control.

A survey of insects that attack toadflax made from June to October, 1953 (Loan, 1954) showed that *B. pulicarius* was widely distributed over Southern Saskatchewan at a low density (Table I). Presumably the beetle had colonized the area some years previously and was still building up its numbers, as Selleck (1961, in litt.) stated that initial work, from 1950 to 1953, revealed that *B. pulicarius* was present through the province only rarely. By 1956 he reported that as a result of the *B. pulicarius* attack much of the toadflax infestation at Parkbeg failed to flower all season and that on 31 July, 1957, bloom was almost entirely absent within a thirty-mile radius of Marsden (Selleck *et al.*, 1957). Toadflax samples taken in 1957 and 1960 at Marsden and Codesa indicate that there was approximately one larva per stem (Table I), an increase of ten- to a hundred-fold over the density in 1953. As a result of this population increase, seed production at Marsden declined to an average of 326 seeds per flowering stem in 1957 and 305 in 1958 – a reduction of over 90 per cent from 1952. At Codesa, seed production was somewhat higher: 961 seeds per flowering stem in

TABLE 1
Distribution and abundance of *B. pulicarius* in Saskatchewan

Area		Average No. of stems per sample	*B. pulicarius* larvae/stems
Marsden	1953	194	.08
Rosthern	1953	235	.06
Kelliher	1953	197	.10
Peebles	1953	437	.05
Mortlach	1953	336	.01
Battle Creek	1953	206	.08
Marsden	20 Sept., 1957	9	1.1
	1 Oct., 1957	12	.8
Codesa	23 July, 1957	4	1.0
	18 Sept., 1957	9	3.3
Codesa	26 Aug., 1960	70	1.0

1957 and 1,090 in 1960 — a reduction of over 80 per cent from 1952. Coincidentally with the increase in the population of *B. pulicarius*, the toadflax rate of spread declined. Although part of the credit for this must go to improved cultural methods of control, these would have been less efficient in the absence of the beetle. Thus, according to Selleck (1961, in litt.) the *B. pulicarius* infestations had the effect of greatly decreasing seed production and decreasing the vigour of the plants so that control by introduced grasses and by tillage methods is more effective. Likewise Carder (1960, in litt.) reported that at Peace River, Alberta, the toadflax infestation had declined.

G. antirrhini

The life history of *G. antirrhini* in Southern Ontario was described by Smith (1959). The adults emerge in May to feed on the young toadflax stems. They pair in June and lay in the young ovary during flowering. The larva feeds on the seeds and pupates inside the capsule. The teneral adults may overwinter in the seed capsules or under debris on the ground. *G. antirrhini* is reproductively mature in the early summer, but few larvae can be found in the field before August, presumably because *B. pulicarius* larvae destroy its eggs when they eat the flowers. However, from August onward toadflax is almost solely attacked by *G. antirrhini*. Thus, though there is some competition between the two species in early summer, from a control point of view *G. antirrhini* supplements *B. pulicarius* by restricting seed production in the fall when the latter species is scarce. Hence, *G. antirrhini* is important in the control of toadflax in Ontario.

In 1957, 2,000 adult *G. antirrhini* were released at Marsden, Saskatchewan, and a similar number at Codesa, Alberta. The release at Marsden was along a fence that separated a cultivated field from rough pasture and was not sheltered by trees or shrubs. Collections made one and two months after the release yielded *G. antirrhini* larvae or pupae in about one-third of the few seed capsules formed at the release point, but no *G. antirrhini* were found in the three subsequent years. The winter temperature reached a low of −35°F. in February, 1958 (Waseca recording station) but lower temperatures were survived by *G. antirrhini* at Codesa. It is believed that the reason for the non-establishment was the high and continuous destruction of flowers by *B. pulicarius* which resulted in a large destruction of *G. antirrhini* eggs and thus reduced survival below replacement level.

TABLE II
The distribution of *G. antirrhini* at Codesa three years after release

Distance from release point	0′	0′*	50′	150′	200′	350′	500′	700′*
Per cent capsule damage by *G. antirrhini*	36.0	56.2	14.3	11.4	16.5	0.9	0	1.1
Per cent capsule damage by *B. pulicarius*	5.5	2.4	0.0	22.8	13.3	30.2	32.8	32.6
No. capsules examined	617	124	105	325	91	998	289	95

*Samples taken 8 September, other samples taken 26 August.

At Codesa *G. antirrhini* is established on toadflax, but has spread less than a thousand feet in three years (Table II). The release was made at the corner of an open thicket containing dense toadflax and surrounded by cultivated fields with sparse toadflax; the site was more sheltered than at Marsden, though the winters were colder, with minimum temperatures of −38°F. in February, 1958, and −53°F. in January, 1959 (Rycroft recording station). Establishment was possible at Codesa, it is believed, because proportionately over three times as many flowers escaped destruction by *B. pulicarius* to form seed capsules as at Marsden. For example from a series of samples taken between July and December, 1957, the average number of seed capsules per stem at Codesa was 12.4 while at Marsden it was only 3.6. Estimates of seed production, given previously, indicate that the number of capsules produced in both places is fairly constant each year. Thus, proportionately about three times as many *G. antirrhini* eggs could survive destruction at Codesa as at Marsden.

When the seed capsules have developed, *B. pulicarius* larvae tend to avoid those containing *G. antirrhini*. Thus, of the 2,644 capsules examined for Table II, only six, all on one stem, were damaged by both *B. pulicarius* and *G. antirrhini*. Moreover, at the release point, where the population of *G. antirrhini* was most dense, the percentage of capsules attacked by *B. pulicarius* was small, but it increased as the *G. antirrhini* density declined with increasing distance from the release point (Table II). Furthermore, though all the plants had been previously attacked, no *B. pulicarius* were found on the 27 stems examined that were collected from within 50 feet of the release point; on the 56 stems examined from between 150 to 200 feet there was an average of 0.86 larvae per stem, and from the 350- to 500-foot mark there was an average of 0.96 larvae on the 70 stems examined. These figures suggest that *G. antirrhini* may be partly responsible for the mid-summer disappearance of *B. pulicarius* in Ontario.

The main result of introducing *G. antirrhini* has been to displace *B. pulicarius* partially. It is however, resulting in a slightly higher total destruction of seeds. In capsules attacked by *B. pulicarius* rarely more than half the 87 ± 8 seeds are destroyed, whereas one *G. antirrhini* larva destroyed all but 8 ± 3 seeds; two larvae in a capsule destroyed all but 2 ± 1 seeds and no seeds remained in capsules containing three or more *G. antirrhini*. There was an average of 1.3 *G. antirrhini* larvae per infested capsule at the release point. However, the increase in seed destruction is so small and the ecological niche occupied by *B. pulicarius* in Saskatchewan and Alberta is so similar to that required by *G. antirrhini*, that further dissemination of the weevil on the prairies does not seem to be justified.

Summary

In Southern Ontario toadflax is attacked by *B. pulicarius*, feeding on buds, flowers and seed capsules, and by *G. antirrhini* feeding inside the capsules on the seeds. Nearly all toadflax buds and flowers are destroyed by *B. pulicarius* in the early summer while in the late summer toadflax is solely attacked by *G. antirrhini*. On the prairies, however, *B. pulicarius* continues attacking toadflax until freeze-up. Introduced *G. antirrhini* failed to become established at Marsden, Saskatchewan, where few toadflax flowers escaped destruction by *B. pulicarius*. On the other hand at Codesa, Alberta, where about three times as many seed capsules were formed as at Marsden, *G. antirrhini* has become established and spread slightly. This establishment was largely at the expense of *B. pulicarius*. Evidence is also presented showing that the rapid spread of toadflax on the prairies occurred in the absence of *B. pulicarius* and that since the beetle has colonized the area, toadflax is a less serious problem.

Acknowledgments

This study was initiated and the releases made by Dr. Morris Smith of the Entomology Research Institute for Biological Control, Belleville, Ontario. All unacknowledged data for 1957 and 1958 have been taken or calculated from Dr. Smith's notes. The interest and help in taking samples of Dr. A. Carder of the Experimental Farm, Beaverlodge, Alberta, and Dr. C. Keyes of the Experimental Farm, Scott, Saskatchewan, is gratefully acknowledged, and also the technical assistance of Miss L. Rollins.

References

Beck, T. V. [1954]. Weed work in Saskatchewan. *Proc. 7th Western Canadian Weed Control Conf.* (1953): 98-100 (processed).

Coupland, R. T., G. W. Selleck, and S. Zilke. 1954. The abundance of persistent perennial weeds in Saskatchewan. *Res. Rept. Nat. Weed Comm.* (*West. Sect.*) 1954: 110-111 (processed).

Frankton, C. 1951. Progress report of federal-provincial weed surveys in Western Canada. *Proc. and Abstr. 5th Western Canadian Weed Control Conf.* 1951: 207-213 (processed).

Loan, L. A. 1954. Progress report on a study of insects found on toadflax, *Linaria vulgaris* Mill., from Saskatchewan and Belleville, Ontario. Ent. Res. Inst. for Biol. Control, Belleville, Ontario. Unpublished.

Selleck, G. W., J. F. Alex, R. T. Coupland, and J. M. Smith. 1957. The effect of *Brachypterolus pulicarius* on toadflax inflorescences. *Res. Rept. Nat. Weed Comm.* (*West. Sect.*) 1957: p. 133 (processed).

Smith, J. M. 1959. Notes on insects, especially *Gymnaetron* spp. (Coleoptera: Curculionidae), associated with toadflax, *Linaria vulgaris* Mill. (Scrophulariaceae), in North America. *Canadian Ent.* 91: 116-121.

Zilke, S., and R. T. Coupland. 1954. *Res. Rept. Nat. Weed Comm.* (*West. Sect.*) 1954: 104-107 (processed).

(Received March 13, 1961)

Biology and Taxonomy of Mites of the Genus *Tarsonemoides* (Acarina: Tarsonemidae) Parasitizing Eggs of Bark Beetles of the Genus *Ips*[1]

By Evert E. Lindquist and William D. Bedard
Department of Entomology and Parasitology
University of California, Berkeley

Introduction

This study was originally undertaken so as to provide information on the life history and ecology of *Tarsonemoides truncatus* (Ewing), to describe for the first time the developmental instars and male, and to redescribe the female of this species. Research soon indicated, however, that a group of closely related species of mites, including *T. truncatus*, was involved and that the problems to be investigated were more complex and extensive than anticipated.

Biological data and descriptions are here presented for *Tarsonemoides truncatus* and three new species, *T. confusus*, *T. plastographus*, and *T. radiatae;* comparative descriptive material is included for *T. gaebleri* Schaarschmidt. Other species of the genus *Tarsonemoides* are associated with *Ips* bark beetles in North America and Asia, but these are not discussed in detail.

Historical review.—The first work done on tarsonemid mites of the Truncatus Group was that of Ewing (1939) who described *Tarsonemus truncatus* on the basis of three females taken from an adult specimen of *Ips oregoni* (Eichhoff). Beer (1954) redescribed the species on the basis of the original three female syntypes of Ewing and designated one of them as lectotype of the species. Both of these authors mentioned the broadly rounded anterior margin of the propodosomal shield covering much of the gnathosoma.

The most significant work of a biological nature conducted on a species of the Truncatus Group was that of Gäbler (1947), who described and illustrated, but did not validly name, both sexes and developmental instars of a species that is associated with *Ips typographus* (Linnaeus) and *I. amitinus* (Eichhoff) in Europe. Gäbler described in detail the habits and life cycle of the mite, observing that females were egg parasites of the bark beetles, and that when producing eggs, they distend in the same manner as pyemotid mites.

The recent work of Schaarschmidt (1959) is the latest to deal with the Truncatus Group. The species with which Gäbler was concerned was properly named (appropriately *gaebleri*), redescribed and illustrated, and placed in the genus *Tarsonemoides* Trägårdh (1905) which was also redefined by Schaarschmidt on the basis of females. In his ecological discussions of the Tarsonemidae, Schaarschmidt presented a summary of Gäbler's work on the feeding habits and life history of *T. gaebleri.* He indicated that he could not confirm Gäbler's observations concerning the parasitic habit or physogastric swelling of these mites. He further stated that no other instances of physogastry or egg parasitism of *Ips* beetles by tarsonemid mites were recorded in the literature, and that any number of species of mites, including pyemotids capable of physogastry, can be found together in such an ecological situation. The present investigation clarifies and largely substantiates the general life habits of *T. gaebleri* as reported by Gäbler.

Materials and methods.—Mites used for life history studies were collected in pine logs infested with *Ips* beetles as follows: *Tarsonemoides truncatus*, associated with *Ips oregoni* in *Pinus jeffreyi* from Tahoma, El Dorado County, California;

[1]Studies performed under partial support from the California State Division of Forestry, the T. B. Walker Foundation, various forest industries, and the National Science Foundation Graduate Fellowship Program.

T. confusus with *I. confusus* in *P. ponderosa* from Grass Valley, Nevada County, California; *T. plastographus* and *T. radiatae* with *I. plastographus* and *I. radiatae*, respectively, in *P. radiata* from Orinda, Contra Costa County, California. Host beetle broods in field collected material were reared at 80°F. ± 10°F. in natural light at Berkeley, California. The emerging beetles were allowed to attack fresh uninfested logs. Individual beetle eggs and mites attacking them were dissected from these logs and reared in Munger cells (Munger, 1942) at 80°F. and 100 per cent relative humidity. Observations were made daily on these individual rearings and from time to time on naturally emerged adults infested with mites.

Locality and host records were augmented by collecting female mites from individuals scattered among hundreds of *Ips* beetles in various curated collections in California. All mites prepared for microscopic examination were mounted in Hoyer's medium on microslides. Satisfactory preparations were obtained even when 70-year-old mite specimens were removed from the host beetle, placed directly in Hoyer's medium, and cleared by gentle heating in the medium.

Holotypes and allotypes of the new species of *Tarsonemoides* described herein, and neallotype and plesiotype specimens of *T. truncatus* (Ewing) are on deposit in the United States National Museum, Washington, D.C. Paratype and plesiotype specimens, representing all of the species of the Truncatus Group of *Tarsonemoides* presently known from North America, have been deposited in the California Insect Survey, University of California, Berkeley, and in the British Museum (Natural History), London.

Life History Studies

The life histories of the four species of *Tarsonemoides* studied and *T. gaebleri* are similar and intimately associated with those of their hosts. Gäbler's (1947) biological observations on *T. gaebleri* were found to be true for the four species described here except as mentioned later. The life history of *T. confusus* is described here in detail in relation to its host. Differences from this life history are mentioned for the other species.

Female mites are phoretic on emerging *Ips* beetles. They are found on either sex of their host, predominantly on the elytral declivity, occasionally on the pronotum, elytra, venter of the abdomen, and between the fore- and mid-coxae. The mites remain motionless and appressed to the host integument, commonly at the base of setae and at the side of, or under, attached hypopi of acaroid mites and phoretic nymphs of uropodoid mites. They are more abundant on beetles emerging early from a successful attack than on later emerging ones.

Eggs of *Ips confusus* are laid individually in niches; frass is packed tightly by the parent beetle in the open end of the niche to close it from the parent gallery. Within seven days, female mites that have left the parent beetles may be found in the egg niches engorging on the beetle eggs.

The proterosoma of engorging females remains intact and in contact with the egg, but the other body regions spread apart on the enlarging spherical surface of the body. When the female reaches a diameter of roughly 0.3 mm. it commences to lay white, translucent, spherical eggs 0.085 mm. in diameter. Engorging continues until the female body diameter is from 0.37 to 0.46 mm. Egg production ceases and the body becomes flaccid and darkens in color. Gäbler (1947) reported the size of the engorged females to be "ca. 3,8 : 3,5 mm" in diameter. But this is thought to be a typographical error as the host egg is only 1 mm. long by 0.5 mm. wide. Females engorge for two days before oviposition, and they lay eggs for three to four days. Contrary to Gäbler's report for *T. gaebleri* the engorged females are motile and change their feeding positions on

the host egg. However, they are unable to move to another niche in the engorged condition. The number of eggs produced varies directly with the food supply available. Normally over 70 eggs will be produced by a single female on a single host egg, but competition with other mites for the same food source (single egg) reduces the number. Limited observations indicate that fungi or bacteria may also affect food supply. In either case, food may become so limited that females will engorge without oviposition. Host eggs nearest the nuptial chamber of the parent beetle have a higher risk of being destroyed by *Tarsonemoides* than those farther away from the nuptial chamber.

The mite eggs hatch in three to four days. The resulting larvae exist in an active state for only a day or two, move little, and may not feed at all. Parallel with Gäbler's observations but contrary to Schaarschmidt's statement on larvae of *Tarsonemoides gaebleri*, our observations show that larvae of four species do not feed on bark beetle eggs and usually have no access to them. Few, if any, mite larvae disperse from the niche where they were born. The larvae cease their movements, distend slightly, and with no ecdysis pass into a "pupal" stage. This inactive, non-feeding form usually lasts two days, occasionally one day, for males and four days, occasionally two days, for females; then ecdysis occurs and adults emerge. Male emergence begins early and is usually complete before that of the female. Males do not show the tendency to disperse that the new females do; instead they spend their time searching among numbers of "pupae" and sometimes a male may carry a "pupa" about with its fourth pair of legs. Males are rather short-lived, and the majority of them probably do not leave the niche where they were born. Females have a heavier integument and can move faster and with more agility than any other form of the mite.

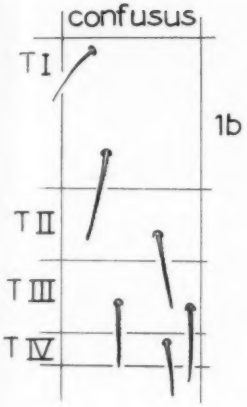
Total developmental time from egg to the adult female mite is six to nine days. Developmental time for the host, under the same conditions, from egg to emergent adult is 27 to 35 days. What the females do for the remaining 21 to 26 days is not positively known but it is unlikely that they complete another generation. Females offered host eggs at this time did not engorge; instead, they remained within the niche, its plug, or dispersed from their birthplace through the plug. Females have been kept up to one month at 80°F. at this point in their life cycle. The ability of the females to maintain themselves for extended periods without engorging allows them to be synchronized with the life cycle of their host. Many areas under the bark are completely opened by the feeding of the new adult beetles prior to their emergence, facilitating mite-beetle contact.

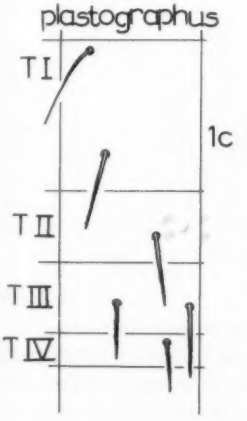
Ips radiatae differs from the three other species of *Ips* in that, instead of ovipositing singly in niches, females usually lay four eggs in each niche, and instead of hatching in four days at 80°F., eggs of *I. radiatae* require seven days. The engorged females of *Tarsonemoides radiatae* are able to move from egg to egg and usually destroy all four eggs. The increased food supply results in a longer oviposition period and greater egg production by female mites. Parent mothers can be found with their eggs, larvae, "pupae" and even new adults, probably as a result of the longer oviposition period.

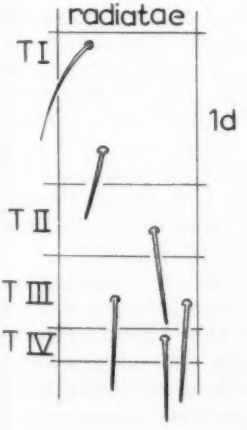
Normally the males of all species occur as five to ten per cent of the adults, but in two cases (one with *Tarsonemoides confusus* and one with *T. radiatae*) the progeny of a female was 100 per cent males. This is thought to be evidence

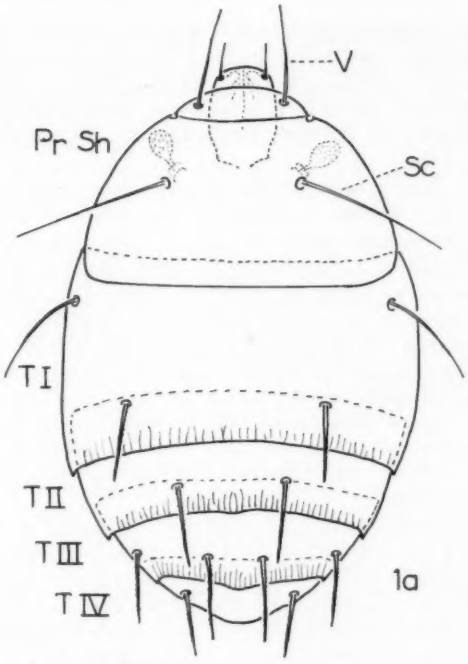
---

Figs. 1-2. 1a, *Tarsonemoides truncatus*, female, body dorsum; 1b-d, relative lengths of setae on one side of tergites I-IV of species of *Tarsonemoides* indicated. 2, *T. truncatus*, female, body venter. See legend of Fig. 4 for abbreviations.

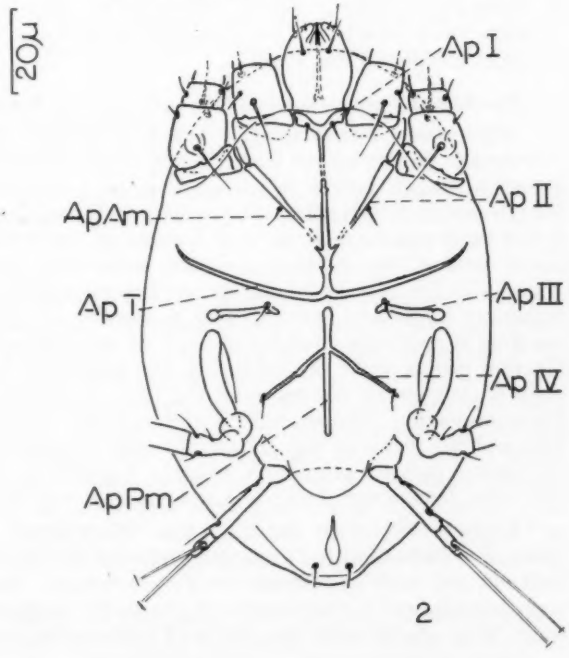

confusus
T I
T II
T III
T IV
1b


plastographus
T I
T II
T III
T IV
1c


radiatae
T I
T II
T III
T IV
1d


V
Pr Sh
Sc
T I
T II
T III
T IV
1a

truncatus


20μ
Ap I
Ap II
ApAm
Ap III
Ap T
Ap IV
ApPm
2

indicating the special type of parthenogenesis known as arrhenotoky, or haplo-diploidy. Arrhenotoky has been well documented for species of Tarsonemini by Cooper (1937), Krczal (1959), Pätau (1936) and Schaarschmidt (1959). Although inbreeding is common, cross-breeding probably occurs between the progeny of females developing on one host egg and more rarely, through dispersal.

The species of *Ips* preyed upon have overlapping distributions but are usually isolated ecologically by variations in the relative abundance and differential host preference of the attacking beetles. The commonly intermixed galleries of *I. radiatae* and *I. plastographus* in maritime areas are an exception. But no instances were found where *Tarsonemoides radiatae* was on *I. plastographus* or *T. plastographus* on *I. radiatae*. Locality and host records for *T. confusus*, *T. oregoni* and *T. radiatae* indicate that some species of beetle host only one species of the Truncatus Group, but that a relationship of opposite exclusiveness is not necessarily true. For example, *I. confusus*, *I. radiatae*, and *I. oregoni* were found bearing only *T. confusus*, *T. radiatae*, and *T. truncatus*, respectively. On the other hand, *T. confusus* was found on *I. montanus*[2], and *T. radiatae* was found on *I. concinnus*[2], a species closely related biologically to *I. radiatae*.

Little can be said about the importance of these mites as bark beetle parasites until the role of egg mortality in the population dynamics of the host has been assessed. But the following observations should merit the inclusion of these mites in population studies of *Ips*. Gäbler reported up to 90 per cent parasitism by *Tarsonemoides gaebleri*. Laboratory populations of *Ips confusus* in Berkeley have had 50 per cent egg loss attributable to *T. confusus*. Individual adult beetles have been collected carrying up to 48, 73, and 80 mites per beetle in the case of *T. confusus*, *T. radiatae*, and *T. plastographus*, respectively. Mites were found virtually every time in the host galleries and niches examined but usually not in numbers as high as those above.

The Genus *Tarsonemoides* Trägardh and the Truncatus Species Group

The genus *Tarsonemoides* Trägårdh (1905) is so closely related to *Tarsonemus* Canestrini and Fanzago (1877) that it may be questioned whether its included species should be recognized as a separate taxon. According to Schaarschmidt (1959), the only characteristic that distinguishes the two genera is that the propodosomal shield of females of *Tarsonemoides* is broadly formed, almost semicircular in shape, covering more than one-half of the gnathosoma (Fig. 1a). On females of the genus *Tarsonemus* this shield is somewhat triangular or trapezoidal in shape, with its anterior margin not broadly formed, and covering at most only the basal one-half of the gnathosoma. On the other hand, the two genera share the following characteristics. The gnathosoma of both sexes is elongate or conical, with the palps cylindrical, longer than wide, and freely projecting. Tibiotarsus I is normal in size, not thicker than those of other legs, and the claws of legs III are normally developed in both sexes. Pseudostigmatic organs are present on females. Legs IV of the males characteristically have stout femora and short tibiae and tarsi that may or may not be fused.

Ewing (1939) early suggested that "*Tarsonemus*" *truncatus* connected the genus *Tarsonemus* with *Pseudotarsonemoides* Vitzthum (1921), but he did not elaborate and made no reference to *Tarsonemoides*. Beer (1954) placed *Pseudotarsonemoides* and *Tarsonemoides* in the family Scutacaridae with no explanation other than stating that the family Tarsonemidae would be restricted as he

[2]Schedl synonymized *I. montanus* under *I. confusus* (1960), and *I. radiatae* under *I. concinnus* (1955).

characterized it. Yet at the end of the same paper *Pseudotarsonemoides* was placed in Tarsopolipodidae and *Tarsonemoides* questionably in Scutacaridae. Schaarschmidt (1959) placed *Pseudotarsonemoides* and *Tarsonemoides* in the family Tarsonemidae on the basis of legs IV in both sexes being strongly dissimilar from the other legs in a manner that is characteristic for other genera included in Tarsonemidae and clearly distinct from legs IV of species of Pyemotidae and Scutacaridae. The concepts of Schaarschmidt are accepted in this paper.

All of the species of *Pseudotarsonemoides* recorded in the literature are known only on the basis of females associated with various genera of scolytoid bark beetles, including *Scolytus*, *Pityogenes*, *Hylesinus*, and *Phloeotribus*. With the exception of legs I being enlarged and the body venter having two additional pairs of setae between legs III and IV, females of *Pseudotarsonemoides* resemble those of *Tarsonemoides*. The life history of species of *Pseudotarsonemoides* is not known, but if it is similar to that of the Truncatus Group, it would explain why there are no male descriptions.

Females of the known species of *Tarsonemoides* that are egg parasites of bark beetles of the genus *Ips* have a number of characteristics in common, and are recognized as a species group which we have named the Truncatus Group. Gravid females of the Truncatus Group are the only ones known in the family Tarsonemidae whose bodies enlarge greatly in the form of a sphere, similar in external appearance to the physogastry of *Siteroptes* in the family Pyemotidae. In contrast to other species of *Tarsonemoides*, the five most posterior pairs of dorsal body setae are conspicuously stout, long, and finely pilose (Fig. 1a-d). The posterior body margin is relatively truncate, somewhat unlike the characteristic oval body shape of most tarsonemids. Males of the Truncatus Group cannot be distinguished from those of other tarsonemids. Males and larvae of species of *Tarsonemoides* outside of the Truncatus Group have not been described in the literature.

Larval and adult instars of species of the Truncatus Group share a large number of morphological characteristics in common. Therefore, a single, detailed description of each of the active instars is given for the group.

Female.—The following description of the female of the Truncatus Group is based on undescribed species of mites on *Ips* beetles from Asia and eastern North America as well as the species from western North America described in this paper.

Gnathosoma elongate, somewhat conical in form, with ventral pair of setae as strongly developed as dorsal pair. General shape of idiosoma oval, but shortened, somewhat truncate posteriorly. Anterior margin of propodosomal shield broad, covering at least basal one-half of gnathosoma (Fig. 1a). Dorsally, posterior setae of tergite I and all setae of tergites II, III, IV conspicuously long, stout, slightly pilose. Vertical and scapular setae of propodosoma, and anterior setae of tergite I slender; vertical setae long; scapulars longest setae of body; anterior setae of tergite I long or short, depending on species. Punctate patterns on propodosomal shield and tergite I, and wavy longitudinal striations on posterior parts of tergites I, II, III absent or present and developed to greater or lesser extent, depending on species. Propodosomal stigmata well separated, lateral to vertical setae.

Apodemes I strongly united to each other and to anteromedian apodeme; anteromedian apodeme strong, extending to transverse apodeme, but with short, weakened area between apodemes I and II in most species (Fig. 2). Apodemes

II straight, strongly joining median apodeme in some species, but weakly or not joining it in others. Coxal setae I and II on or immediately behind apodemes I and II, respectively; distance between coxal setae II about four times that between coxal setae I. Pseudostigmatic organs large, oval, finely, sparsely spiculate. Posteromedian apodeme undivided, extending anteriorly to level of apodemes III and posteriorly to level of anterior margins of trochanters IV. Apodemes III with characteristic shape, extending only medially from anterior extremity of trochanters III to positions of anterior coxal setae III. Apodemes IV straight or slightly undulate, united to each other and to posteromedian apodeme, extending posterolaterally to positions of posterior coxal setae III.

Leg I shorter than leg II; single claw of leg I and paired claws of legs II-III strongly formed, with large ambulacra. Leg setation: that of coxal plates given above; all trochanters without setae; setae short, simple, unless otherwise stated. Leg I: femur with three setae; genu with four setae; tibiotarsus I with 16 setae (Fig. 6a) combining setation of tibia I and tarsus I of male, but lacking two smallest setae of tarsus I of male[2]. Leg II: femur with three setae; genu with three setae; tibia with one short and three longer setae; tarsus with six setae including one sensory club, one dorsal and one ventrodistal spine, and three simple setae (Fig. 6b). Leg III: femurogenu with three setae; tibia with four setae of which two or three longer than others; tarsus with four setae including one ventrodistal spine, one long dorsal seta, and two shorter setae of which one may or may not be spinate (Fig. 6c). Sensory club of tarsus II not as strongly developed as on male. Tibiotarsus I blunt, rounded apically; tarsus II attenuate apically, nearly as long as tibiotarsus I. Leg IV with normal four setae: apical segment with straight subapical seta longer than free part of leg, and with extremely long, whiplike apical seta; subapical segment with one small proximal seta and one stout, straight subapical seta.

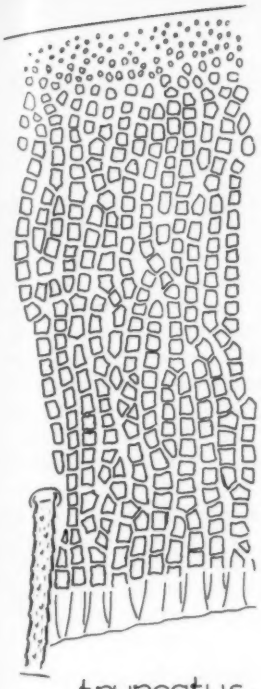
Male.—Males of species of the Truncatus Group in North America resemble closely the only heretofore described male of the group, *Tarsonemoides gaebleri* Schaarschmidt (1959).

Gnathosoma like that of female. General shape of idiosoma roundish, with width subequal to length from anteromedial vertical to sacral setae. Dorsally, posterolateral scapular setae and three pairs of setae on metapodosomal shield especially long; posterolateral vertical and sacral setae short; anteromedial vertical setae one and one-half to two times as long as posterolateral vertical setae; anteromedial scapular setae long or short, depending on species. Scapular setae not in transverse row, one pair posterolateral to other pair. Integument of body and appendages without apparent ornamentation.

Ventrally on body, apodemes I strongly united to each other and to anteromedian apodeme; anteromedian apodeme well developed along anterior one-half to two-thirds of distance between apodemes I and II, but interrupted or weakened along remainder of distance to apodemes II, then strengthened from there to transverse apodeme. Apodemes II curving posteriorly, with their junction near transverse apodeme. Coxal setae I and II well behind apodemes I and II, respectively; distance between coxal setae II twice that between coxal setae I. Posteromedian apodeme bifurcate along posterior one-third to one-half of its length.

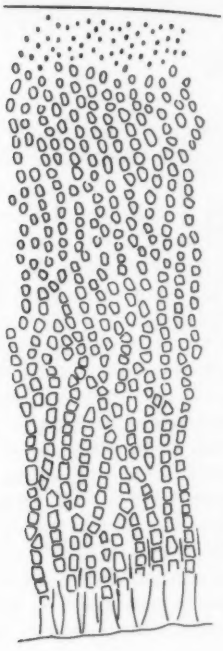
[2]An exception is tibiotarsus I of *T. gaebleri* which lacks four of the smaller setae, according to Schaarschmidt (1959).

Figs. 3a-d, punctation on longitudinal section of tergite I, females of species of *Tarsonemoides* indicated.



3a

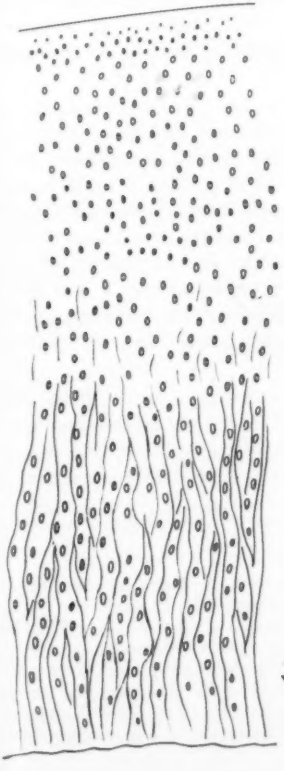
truncatus



3b

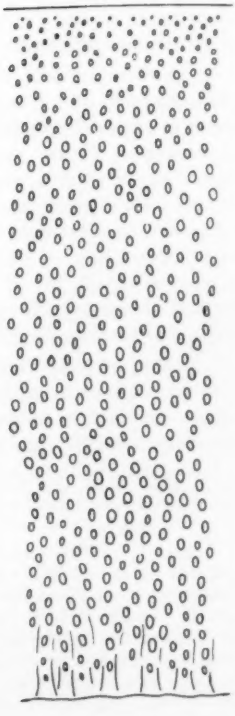
confusus

0.1



3d

radiatae



3c

plastographus

Anterior margins of coxae III and IV flattened, roughly continuous, slanting slightly posteromedially. Genital capsule about as wide as long.

Leg I shorter than leg II which in turn shorter than leg III; single claw of leg I and paired claws of legs II-III strongly formed, with large ambulacra. Tarsus I blunt, rounded apically, longer than tibia I; tarsus II attenuated apically, longer than tibia II. Leg setation: like that of female except as follows. Leg I: tibia with eight setae including one smaller sensory club very near a larger one, one long dorsal seta, one moderately long ventral seta, and four shorter setae of which one closely beside larger sensory club; tarsus with 10 setae including one sensory club, four blunt-tipped apical setae, one ventrodistal spine, and four small setae of which one may be spinate (Fig. 7a)[4]. Leg II: sensory club of tarsus strongly developed, as large as adjacent spine (Fig. 7b). Leg III: femur with one seta; genu with three setae; tarsus with three setae including one ventrodistal spine, one long dorsal seta, and one shorter seta which may or may not be spinate (Fig. 7c). Leg IV (Figs. 5a-d): trochanter roughly quadrangular, at least as wide as long, with one seta; femur stout, one-half to as wide as long, with three setae of which inner distal seta longest; base of proximal femoral seta closely associated with small flange on inner surface of femur; tibia with one very long tactile seta and one rod-shaped sensillum about as long as width of tarsus IV; tarsus with three minute setae and large terminal claw.

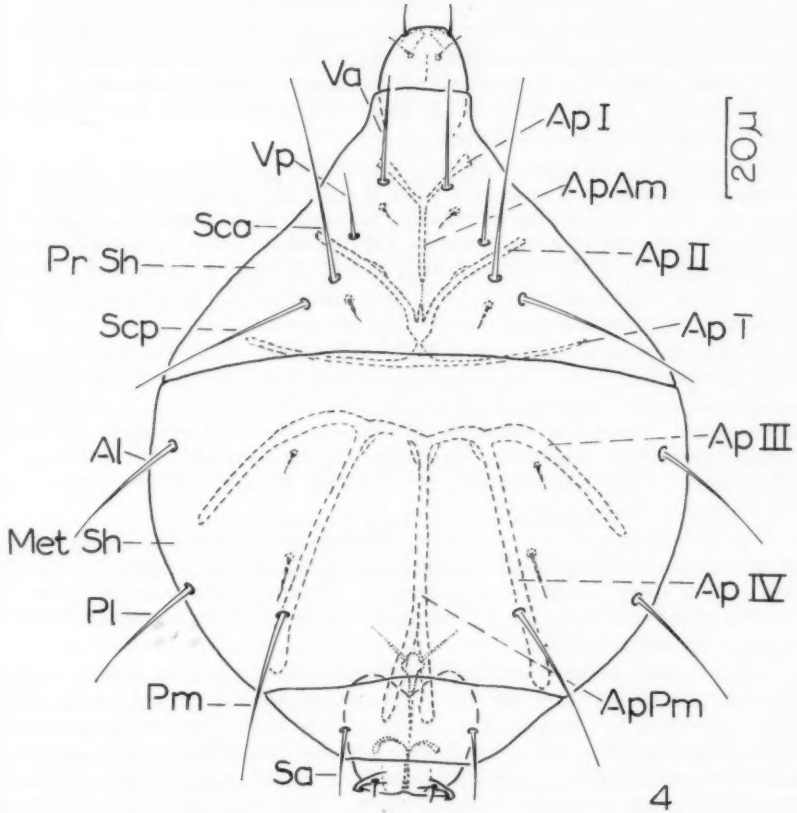
Larva.—Larvae of the Truncatus Group closely resemble the generalized tarsonemid larva described by Schaarschmidt (1959). However, setae of larvae are shorter and finer than those of females in the Truncatus Group. No sexual dimorphism was observed, but the larvae examined were probably all females. The species of the Truncatus Group cannot be distinguished readily on the basis of larval characteristics.

Gnathosoma like that of adults. Dorsal surface of idiosoma covered by propodosomal and four tergital shields. Stigmatal openings and associated tracheae present on anterolateral margins of propodosomal shield, less distinct than on females. Unlike female, gnathosoma not covered at all by propodosomal shield, dorsal shields without extensive overlap, propodosomal shield and tergite II with lateral margins not extending onto lateral body surfaces, and dorsal shields without ornamentation. Chaetotaxy of dorsal shields like that of female, except with second pair of small scapular setae. Posterior setae of tergite I, and setae of tergites II, III, IV all relatively long, stout, finely pilose, as on female; relative lengths of these setae only partly reflective of those on female and not readily usable for taxonomic differentiation of species.

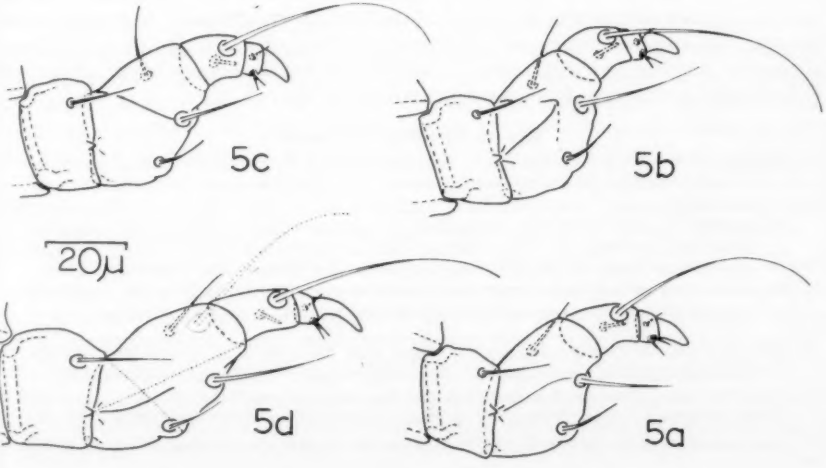
Venter of propodosoma like that of female, with anteromedian apodeme, and with coxal plates I and II bordered by apodemes I and II; but transverse apodeme absent, its position indicated by longitudinal striations of lateral body membrane infolding towards each other on ventrolateral surfaces at level behind prominent

[4]As indicated in the description of *T. gaebleri* that follows, tarsus I and tibiae I, II, III illustrated by Schaarschmidt (1959) lack the full setal complement defined in the Truncatus Group description; whether these illustrations are entirely accurate is not certain.

Figs. 4-5. 4, *Tarsonemoides confusus*, male, body dorsum, with structures of body venter indicated by dotted lines. 5a-d, leg IV of males. 5a, *T. truncatus;* 5b, *T. confusus;* 5c, *T. plastographus;* 5d, *T. radiatae.* Abbreviations: Al, anterolateral seta of metapodosomal shield; Ap I-IV, apodemes I-IV; Ap Am, anteromedian apodeme; Ap Pm, posteromedian apodeme; Ap T, transverse apodeme; Met Sh, metapodosomal shield; Pl, posterolateral seta of metapodosomal shield; Pm, posteromedial seta of metapodosomal shield; Pr Sh, propodosomal shield; Sa, sacral seta; Sc, scapular seta; Sca, anteromedial scapular seta; Scp, posterolateral scapular seta; T I-IV, tergites I-IV; V, vertical seta; Va, anteromedial vertical seta; Vp, posterolateral vertical seta.


Va
Vp
Sca
Pr Sh
Scp
Al
Met Sh
Pl
Pm
Sa
Ap I
ApAm
Ap II
Ap T
Ap III
Ap IV
ApPm
20μ

4


5c
5b
20μ
5d
5a

transverse fold of dorsal body membrane between propodosomal and first tergital shields; coxal plates II not extending posteriorly to indicated position of transverse apodeme; strip of transversely striate membranous cuticle behind posterior margins of coxal plates II connecting laterally with longitudinally striate, lateral body membrane, and posteromedially with longitudinally striate membrane between coxal plates III. Anteromedian apodeme extending posterad to membranous cuticle. Coxal setae I and II located more posteriorly from apodemes I and II, respectively, than on females.

Venter of hysterosoma without apodemes, with large areas covered by coarsely striate membranous cuticle. Coxal plates III reduced in area, separated from each other medially by membrane, not extending anteriorly to indicated position of transverse apodeme; anterior and posterior setae of coxae III on margins of plates[5]. Posteroventral extremity of hysterosoma covered by shield continuous laterally with tergite IV, with prominent pair of stout, pilose external caudal setae and minute pair of smooth internal caudal setae.

Unlike adults, larvae with legs I, II, III very similar except for shape of coxal plates; all legs six-segmented including coxal plates; each tarsus with ambulacrum bearing two claws. Setation of segments of legs I, II, III like that of male except less prominent, tibia I, femur II, tarsus II with one less small seta each, and tarsus I with only six setae, lacking two blunt-tipped apical setae and two small setae of male setation. Body dimensions of larvae about 15 to 30 per cent larger than those of females for each species.

The resting "pupal" form is not a separate instar. It is not distinguishable morphologically from larvae and is not preceded by ecdysis. Alive, it is characterized by a turgid, immotile appearance. Mounted specimens can only be identified when the developing adult instar structures have materialized within the larval integument.

Measurements of mites.—Body measurements were made as follows: length of females and larvae, from anterior margin of propodosomal shield to posterior margin of tergite IV; length of males, from anterior margin of propodosomal extension over gnathosoma to level of sacral setae; width of females and larvae, distance between anterior setae of tergite I; width of males, distance between anterolateral setae of metapodosomal shield. The range of body dimensions among a number of specimens of one species expresses simple difference in sizes, and to a lesser extent the degree of dorsoventral compression from microslide preparation, and on females variation in the amount of retraction or extension of successive tergites into each other. Length and width measurements of femora IV of males were made from positions shown by dotted lines in Fig. 5d.

Key to Species: Females

1. Apodemes II strongly connected to anteromedian apodeme; anteromedian apodeme without weakened area between apodemes I and II; dorsal shields without ornamentation ..... *gaebleri*
   Apodemes II weakly or not connected to anteromedian apodeme; anteromedian apodeme weakened for short distance between apodemes I and II (Fig. 2); propodosomal shield and tergite I with more or less distinct ornamentation 2
2. Posterior setae of tergite I shorter than lateral setae of tergite III (Fig. 1d); punctate ornamentation of propodosomal shield and tergite I faintly developed (Fig. 3d). ..... *radiatae*
   Posterior setae of tergite I equal to or longer than lateral setae of tergite III; punctate ornamentation of propodosomal shield and tergite I conspicuously developed. 3
3. Posterior setae of tergite I longer than anterior setae of tergite I (Fig. 1b) ..... *confusus*
   Posterior setae of tergite I equal to or shorter than anterior setae of tergite I. 4

[5]Schaarschmidt (1959) did not indicate the presence of posterior setae of coxae III on the generalized larva.

4. Posterior setae of tergite I usually slightly longer than setae of tergite II and medial setae of tergite III (Fig. 1c); puncta on tergite I all elliptical, becoming neither larger nor closer together in longitudinal rows weakly arranged on posterior half of shield (Fig. 3c). ..... *plastographus*
Posterior setae of tergite I subequally as long as setae of tergite II but usually slightly shorter than medial setae of tergite III (Fig. 1a); puncta on tergite I mostly quadrangular, becoming larger and closer together posteriorly in longitudinal rows well arranged along entire length of shield (Fig. 3a). ..... *truncatus*

Males

1. Anteromedial scapular setae shorter than anteromedial vertical setae and less than one-half as long as posterolateral scapular setae; tarsi I, III each with two spines. ..... *gaebleri*
Anteromedial scapular setae longer than anteromedial vertical setae and subequally as long as posterolateral scapular setae; tarsi I, III each with one spine. 2
2. Width of femur IV about two-thirds to three-fourths its length (Fig. 5d) ..... *radiatae*
Width of femur IV about seven-eighths to nine-tenths its length (Figs. 5a-c) 3
3. Metapodosomal shield with anterolateral setae subequally as long as posteromedial setae and longer than posterolateral setae. ..... *truncatus*
Metapodosomal shield with anterolateral setae subequally as long as posterolateral setae and shorter than posteromedial setae (Fig. 4). 4
4. Ventral surface of femur IV with ridge extending from point of articulation with trochanter to a point short and medial of inner distal seta (Fig. 5b). ..... *confusus*
Ventral surface of femur IV with ridge extending from outer basal angle of contact with trochanter diagonally to base of inner distal seta (Fig. 5c). ..... *plastographus*

Tarsonemoides gaebleri Schaarschmidt

Pseudotarsonemoides sp. Gäbler, 1947:113-115; Figs. 1a-e, 2, 3.
Tarsonemus gaebleri Schaarschmidt, *in* Hirschmann and Rühm, 1953:8; Fig. 4; *in* Hirschmann and Rühm, 1954:43-44; Fig. 5. *Nomen nudum*[8].
Tarsonemoides gaebleri Schaarschmidt, 1959:780-782; Figs. 3a, 4b, 8b, 10a-d, 35a-d, 36a-b.

The following descriptions are based on the original descriptions of Schaarschmidt, supplemented by characteristics illustrated but not described by him. The accuracy of the illustrations has been confirmed by Schaarschmidt in personal correspondence (Jan. 2, 1961).

Diagnosis.—The absence of ornamentation on the body dorsum, and the strongly formed apodemes on the propodosomal venter distinguish the female. Males are characterized by short anteromedial scapular setae and a second spine on tarsi I and III.

Female.—Propodosomal shield and tergite I smooth, without punctate or striate ornamentation. Posterior setae of tergite I slightly longer than anterior setae of tergite I and setae of tergite II, and about as long as medial setae of tergite III; lateral setae of tergite III shorter than setae of tergite IV. Anteromedian apodeme strongly formed along entire length, with neither short weakened area nor enlarged knob between apodemes I and II; apodemes II strongly connected to anteromedian apodeme. Tibiotarsus I illustrated with only eight setae (four less than on other species of Truncatus Group) in addition to three sensory clubs and one ventrodistal spine. Body dimensions: length 125-133μ, width 73-77μ.

Male.—Posterolateral scapular setae illustrated as two and one-half times longer than anteromedial scapular setae; on metapodosomal shield, posteromedial setae illustrated as longest setae of body, slightly longer than posterolateral setae; anterolateral metapodosomal setae illustrated as about four-fifths as long as posterolateral metapodosomal setae and slightly shorter than posterolateral scapular

[8]In accordance with the International Code of Zoological Nomenclature adopted by the XV International Congress of Zoology, London, July, 1958 (in press), it is here considered that Hirschmann and Rühm (1953, 1954) did not validate a manuscript name of Schaarschmidt since they provided that name with neither a descriptive statement purporting to give characters differentiating the species concerned, nor a definite bibliographic reference to such a statement.

setae. Tarsus I with dorsal spine in addition to ventrodistal spine; tarsus III with two spines and one long seta. Tibia II and III each illustrated with only three long setae, but fourth smaller seta perhaps overlooked; tibia I illustrated with four setae (two less than on other species of group) and one sensory club, but the smaller, adjacent, second sensory club, shown on female, perhaps overlooked; tarsus I illustrated with one less small seta than on other species of group. Body dimensions: length 115-125μ, width 80-85μ.

Locality and host records.—Kirchberg a.d. Jagst, Baden-Württemburg, Germany, July 4, 1951 (L. Schaarschmidt), in galleries of *Ips typographus* (Linnaeus). Gäbler recorded *I. amitinus* (Eichhoff) as well as *I. typographus* as a host, but whether the same species of *Tarsonemoides* was involved is uncertain.

Tarsonemoides truncatus (Ewing), new combination

(Figs. 1a, 2, 3a, 5a)

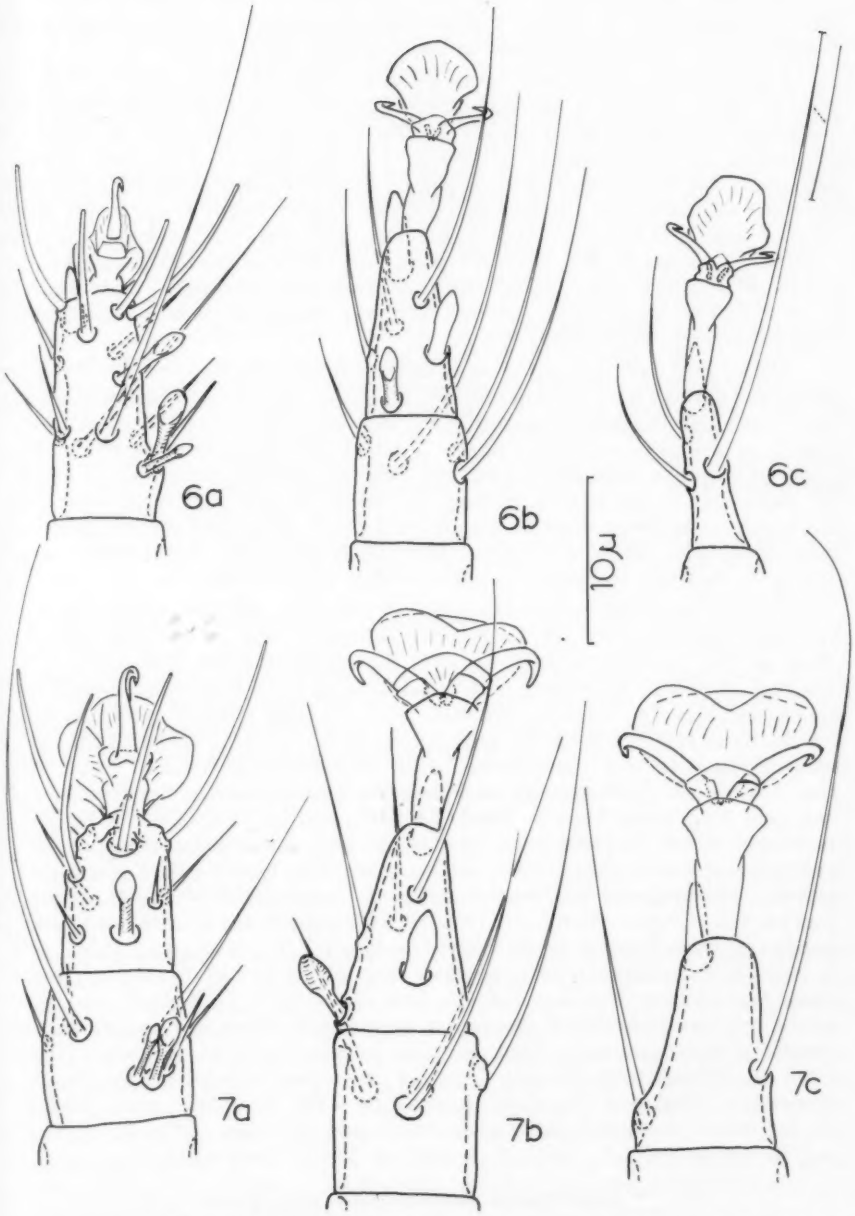
Tarsonemus truncatus Ewing, 1939:49-50; Figs. 17a-b; Beer, 1954:1220-1221; Schaarschmidt, 1959:779.

Diagnosis.—Females are distinguished by puncta on tergite I being large, quadrate, developed more than on any other species described, and by relative lengths of setae on tergites I, II, III. Males are identified by relative lengths of metapodosomal setae, and by structure of femur IV.

Female.—Puncta on propodosomal shield relatively large, separated by one- to three-fourths their diameter. Puncta of tergite I mostly quadrangular, large, close together in longitudinal rows well arranged along entire exposed length of shield, becoming larger towards posterior margin of shield; width of rows of puncta greater than narrow longitudinal interstices between them. Posterior setae of tergite I shorter than anterior setae of tergite I, about as long as setae of tergite II, usually slightly shorter than medial setae of tergite III. Anteromedian apodeme between apodemes I and II with short, weakened area bordered posteriorly by small knoblike thickening; apodemes II not or weakly connected to anteromedian apodeme. Body dimensions: lectotype, length 113μ, width 73μ; range among 16 other specimens, length 99-127μ, width 66-75μ.

Male.—Two pairs scapular setae subequal in length, the longest setae of body; anteromedial vertical setae about two-thirds as long as scapular setae; metapodosomal shield with posterolateral setae about three-fourths as long as subequal anterolateral and posteromedial setae. Tarsus I with single spine ventrodistally; tarsus III with one spine ventrodistally, one long seta, and one shorter seta. Femur IV about seven-eighths as wide as long, its ventral surface with ridge delineated from basal articulation with trochanter to base of inner distal seta. Body dimensions: neallotype, length 129μ, width 96μ; range among three other specimens, length 122-127μ, width 96-101μ.

Locality and host records.—Lectotype and two syntypes: females, Coeur d'Alene, Kootenai Co., Idaho, Aug. 15, 1931 (H. J. Rust), on *Ips oregoni;* type no. 1135 in the U. S. National Museum. Plesiotypes: four females, mountains west of La Grande, Union Co., Oregon, July 10, 1922, on *I. oregoni;* two females, Baker, Baker Co., Oregon, July 8, 1922, on *I. oregoni;* three females, Crater Lake, Klamath Co., Oregon, July 24, 1938 (K. M. Fender), on *I. oregoni;* 12 females, Carrville, Trinity Co., Calif., June 7 and 22, 1913, on *I. oregoni;* eight females, Sierraville, Sierra Co., Calif., July 9, 1954 (R. H. Goodwin), on *I. oregoni*; 44 females, four males, and eight larvae, Tahoma, El Dorado Co., Calif., Sept. 5, 1960 (W. D. Bedard), associated with *I. oregoni* infesting *Pinus jeffreyi,* reared at Berkeley in *P. ponderosa;* 13 females, Huntington Lake, Fresno Co., Calif., July 11, 1919 (E. P. Van Dyke), July 16, 1919 (F. E. Blaisdell), July 17, 1919 (Helen Van Duzee), on *I. oregoni* from *Pinus* sp.



Figs. 6-7, *Tarsonemoides confusus*, right legs, dorsal view. 6a, tibiotarsus I, female; 6b, tibia and tarsus II, female; 6c, tarsus III, female. 7a, tibia and tarsus I, male; 7b, tibia and tarsus II, male; 7c, tarsus III, male.

Tarsonemoides confusus, new species

(Figs. 1b, 3b, 4, 5b, 6a-c, 7a-c)

Diagnosis.—Short anterior setae, long posterior setae, and degree of development of punctation on tergite I characterize the female. Relative lengths of metapodosomal setae and structure of femur distinguish the male.

Female.—Puncta on propodosomal shield large, separated by one-half to equal their diameter. Puncta of tergite I mostly elliptical along anterior half of shield, becoming more or less quadrangular on posterior half; puncta well arranged in longitudinal rows on posterior two-thirds of shield, lying closer together within each row and becoming slightly larger, if at all, towards posterior of shield. Posterior setae of tergite I longer than anterior setae of tergite I, and longer than setae of tergites II, III, IV. Anteromedian apodeme between apodemes I and II with short weakened area bordered posteriorly by small knoblike thickening; apodemes II not or weakly connected to anteromedian apodeme. Body dimensions: holotype, length 119μ, width 78μ; range among 23 paratype specimens, length 108-136μ, width 66-80μ.

Male.—Two pairs scapular setae subequal in length, the longest setae of body; anteromedial vertical setae about one-half as long as scapular setae; metapodosomal shield with anterolateral and posterolateral setae subequally long and about three-fourths as long as posteromedial setae. Tarsus I with single spine ventrodistally; tarsus III with one ventrodistal spine, one long seta, and one shorter seta. Femur IV about nine-tenths as wide as long, its ventral surface with ridge delineated from basal articulation with trochanter to a point lateral and slightly short of inner distal seta. Body dimensions: allotype, length 132μ, width 106μ; range among 23 paratype specimens, length 110-141μ, width 78-106μ.

Locality and host records.—Holotype: female, 5 mi. east Nevada City, Nevada Co., Calif., Oct. 23, 1959 (W. D. Bedard), associated with *Ips confusus* infesting *Pinus ponderosa*, reared at Berkeley in *P. ponderosa;* type no. 2753 in the U. S. National Museum. Paratypes: two females, Santa Cruz mountains, Santa Cruz Co., Calif., May 26, 1942 (H. Madsen), on *I. confusus* from *P. ponderosa;* one female, Ryan Hill, Stanford, Santa Clara Co., Calif., Feb. 11, 1930 (H. E. Burke), on *I. confusus* from *P. radiata;* one female, Oakland hills, Alameda Co., Calif., Dec. 1, 1938 (W. E. Ferguson), on *I. confusus* from *P. radiata;* five females and one male, 1 mi. north Angwin, Napa Co., Calif., April 22, 1959 (W. D. Bedard), associated with *I. confusus* infesting *P. ponderosa;* two females, above Caribou Lake, elev. approx. 8,000 ft., Siskiyou Co., Calif., Aug. 2, 1942 (W. E. Ferguson), one on *I. confusus*, one on *I. montanus*, from *P. monticola;* two females, Ashland, Jackson Co., Oregon, March 21, 1916 (P. D. Sergent), on *I. confusus* from *P. ponderosa;* three females, 15 mi. north Hat Creek P. O., Shasta Co., Calif., July 6, 1955 (E. E. Lindquist), on *I. confusus* from *P. jeffreyi;* six females and seven males, Grass Valley, Nevada Co., Calif., May 17, 1960 (W. D. Bedard), associated with *I. confusus* infesting *P. ponderosa*, reared at Berkeley in *P. ponderosa;* 12 females of which seven engorged, 15 males including allotype, and seven larvae, 5 mi. east Nevada City, Nevada Co., Calif., same data as holotype; five females, Strawberry, Tuolomne Co., Calif. July 10, 1958 (D. L. Wood), on *I. confusus* from *P. murrayana* and *P. lambertiana;* one female, Wawona, Mariposa Co., Calif. (G. R. Struble and J. S. Yuill), on *I. confusus* from *P. lambertiana.*

Tarsonemoides plastographus, new species

(Figs. 1c, 3c, 5c)

Diagnosis.—Females are identified by the relative lengths of setae on tergites I, II, III, and by puncta on the propodosomal shield and tergite I being elliptical,

small, less developed than on *Tarsonemoides confusus* and *T. truncatus*. Males are distinguished by the structure of femur IV and by relative lengths of the metapodosomal setae.

Female.—Puncta on propodosomal shield relatively small, separated by one and one-half to three times their diameter. Puncta of tergite I all elliptical, becoming neither larger nor closer together towards posterior margin, and weakly arranged in longitudinal rows on posterior one-half of shield. Posterior setae of tergite I equal to or shorter than anterior setae of tergite I, and usually slightly longer than setae of tergite II and median setae of tergite III. Anteromedian apodeme between apodemes I and II with short, slightly weakened area bordered posteriorly by small knoblike thickening; apodemes II not or weakly connected to anteromedian apodeme. Body dimensions: holotype, length 128μ, width 75μ; range among nine paratypes, length 119-136μ, width 66-78μ.

Male.—Two pairs scapular setae subequal in length, the longest setae of body; anteromedial vertical setae about one-half as long as scapular setae; metapodosomal shield with anterolateral and posterolateral setae subequal in length and about three-fourths as long as posteromedial setae. Tarsus I with single spine ventrodistally; tarsus III with one ventrodistal spine, one long seta, and one shorter seta. Femur IV about nine-tenths as wide as long, its ventral surface with ridge not delineated from basal articulation with trochanter, but with extent of swollen basal area delimited by line running from outer basal angle to base of inner distal seta. Body dimensions: allotype, length 122μ, width 99μ; range among four paratypes, length 127-134μ, width 85-103μ.

Locality and host records.—Holotype: female, Orinda, Contra Costa Co., Calif., Sept. 22, 1960 (W. D. Bedard), associated with *Ips plastographus* from *Pinus radiata;* type no. 2754 in the U. S. National Museum. Paratypes: five females, Carmel, Monterey Co., Calif., May 19, 1930 (L. S. Slevin), on *I. plastographus* from *P. radiata;* eight females, Pacific Grove, Monterey Co., Calif. (no other data), on *I. plastographus;* five females, four males including allotype, and two larvae, Orinda, Contra Costa Co., Calif., Sept. 22, 1960 (W. D. Bedard) and one engorged female, same locale, Oct. 13, 1960 (W. D. Bedard and E. E. Lindquist), associated with *I. plastographus* from *P. radiata.*

Tarsonemoides radiatae, new species

(Figs. 1d, 3d, 5d)

Diagnosis.—The weak development of punctation on the propodosomal shield and tergite I, plus the short posterior setae of tergite I and long setae of tergites II, III, IV characterize the female. Males are recognized by relatively elongate legs IV, especially the femora.

Female.—Puncta on propodosomal shield weakly developed, small, separated by two to four times their diameter. Puncta of tergite I weakly developed, all elliptical, not becoming larger towards posterior margin, and poorly arranged in longitudinal rows along comparatively well developed striations on posterior two-thirds of shield. Posterior setae of tergite I shorter than anterior setae of tergite I and all setae of tergites II, III, IV; medial setae of tergite III slightly the longest of setae of tergites II, III, IV. Anteromedian apodeme between apodemes I and II with short, slightly weakened area bordered posteriorly by small knoblike thickening; apodemes II not or weakly connected to anteromedian apodeme. Body dimensions: holotype, length 146μ, width 87μ; range among 17 paratypes, length 141-165μ, width 78-92μ.

Male.—Two pairs of scapular setae subequal in length, the longest setae of body; anteromedial vertical setae about two-thirds as long as scapular setae; meta-

podosomal shield with posterolateral setae usually slightly shorter than subequally long anterolateral and posteromedial setae. Tarsus I with single spine ventrodistally; tarsus III with one ventrodistal spine, one long seta, and one shorter seta. Trochanter IV subequally as long as wide; femur IV about two-thirds as wide as long. Ventral surface of femur IV with ridge delineated for short distance from basal articulation with trochanter to a point on level with but laterad of inner proximal seta. Body dimensions: allotype, length 127μ, width 110μ; range among 14 paratypes, length 110-139μ, width 82-113μ.

Abnormal variations on two males are noteworthy. The very long sensory seta of tibia IV is duplicated near the distal extremity of the preceding segment on just one of the legs; the abnormal seta is indicated by dotted lines in Fig. 5d. Another paratype has the posteromedial seta duplicated on just one side of the metapodosoma.

Locality and host records.—Holotype: female, 0.5 mi. east Monterey Peninsula Airport, Monterey Co., Calif., Oct. 15, 1960 (E. E. Lindquist), on *Ips radiatae* from *Pinus radiata;* type no. 2755 in the U.S. National Museum. Paratypes: 10 females, 0.5 mi. east of Monterey Peninsula Airport, Monterey Co., Calif., same data as holotype; one female, Berkeley Hills, Alameda Co., Calif., July 30, 1959 (R. W. Stark and J. A. Chemsak) and six females, same locale (W. D. Bedard), on *I. radiatae* from *P. radiata;* 14 females including two engorged, 12 males including allotype, and 13 larvae, Orinda, Contra Costa Co., Calif., Oct. 13, 1960 (W. D. Bedard and E. E. Lindquist) and seven females, three males, and three larvae, same locale, Oct. 20, 1960 (W. D. Bedard), associated with *I. radiatae* infesting *P. radiata;* two females, Florence, Lane Co., Oregon, June 12, 1936, on *I. concinnus* (det. by S. L. Wood).

Summary

1. The genus *Tarsonemoides* is characterized, and its biological and morphological relationships with other taxa of the Tarsonemini are discussed.
2. Life history studies of four species of *Tarsonemoides* associated with *Ips* are presented. Females of these species undergo a form of physogastry while parasitizing eggs of *Ips;* larvae and males neither parasitize *Ips* eggs nor require the presence of any form of the host for activity and development.
3. The Truncatus Species Group of *Tarsonemoides* is defined biologically and morphologically; descriptions for larva, male, and female of the group are given.
4. Keys and diagnoses for males and females of the known species of the Truncatus Group are presented.
5. The female of *Tarsonemoides truncatus* (Ewing), new combination, is redescribed, and the previously unknown male is described.
6. The sexes of the following new species are described: *Tarsonemoides confusus, T. plastographus,* and *T. radiatae.*

Acknowledgments

Particular thanks are due the following specialists for their assistance in obtaining specimens or examining type specimens: Dr. Edward W. Baker, United States National Museum, Washington, D.C.; Dr. William E. Ferguson, University of California, Berkeley; Mr. Frank H. Haramoto, University of Hawaii, Honolulu; Dr. Ludwig Schaarschmidt, Göppingen, Germany. The cooperation of the California Academy of Sciences, San Francisco, the California Insect Survey, University of California, Berkeley, and the Pacific Southwest Forest and Range Experiment Station, Berkeley, in making their collections available is gratefully acknowledged. Finally, we appreciate the critical review of this manuscript by

Dr. Paul D. Hurd, Jr., Dr. A. Earl Pritchard, and Dr. Ronald W. Stark, University of California, Berkeley.

References

Beer, R. E. 1954. A revision of the Tarsonemidae of the Western Hemisphere (Order Acarina). *Univ. Kansas Sci. Bull.* 36, Pt. 2(16):1091-1387.

Canestrini, G., and F. Fanzago. 1877. Nuovi Acari Italiani. *Atti d. Soc. Veneto-Trentina di Sci. Nat.* 5(1):99-111, 130-142.

Cooper, K. W. 1937. Reproductive behavior and haploid parthenogenesis in the grass mite, *Pediculopsis graminum* (Reut.) (Acarina, Tarsonemidae). *Proc. Natl. Acad. Sci.* 23(2):41-44.

Ewing, H. E. 1939. A revision of the mites of the subfamily Tarsoneminae of North America, the West Indies, and the Hawaiian Islands. *U. S. Dept. Agr. Tech. Bull.* 653:1-63.

Gäbler, H. 1947. Milbe als Eiparasit des Buchdruckers (*Ips typographus* L.). *Nachrichtenblatt für den Deutschen Pflanzenschutzdienst* 1(7-8):113-115.

Hirschmann, W., and W. Rühm. 1953. Milben und Fadenwürmer a!s Symphoristen und Parasiten des Buchdruckers. *Mikrokosmos* 43(1): 7-10.

Hirschmann, W., and W. Rühm. 1954. Milben und Fadenwürmer als Symphoristen und Parasiten des Buchdruckers (*Ips typographus*). *Nachrichten des Naturw. Museums der Stadt Aschaffenburg* Heft 43:41-50; 7 pl.

Krczal, H. 1959. Systematik und Ökologie der Pyemotiden. *Beiträge zur Systematik und Ökologie Mitteleuropäischer Acarina* 1, Teil 2, Abschnitt 3: 385-625.

Munger, F. 1942. A method for rearing citrus thrips in the laboratory. *J. Econ. Ent.* 35(3): 373-375.

Pätau, K. 1936. Cytologische Untersuchungen an der haploidparthenogenetischen Milbe *Pediculoides ventricosus* Newp. Berl. *Zool. Jahrb.* 56(3): 277-322.

Schaarschmidt, L. 1959. Systematik und Ökologie der Tarsonemiden. *Beiträge zur Systematik und Ökologie Mitteleuropäischer Acarina* 1, Teil 2, Abschnitt 5: 713-823.

Schedl, K. E. 1955. Die Kiefern-Borkenkäfer Guatemalas. *Z. angew. Ent.* 38(1): 1-48.

Schedl, K. E. 1960. Synonymies of bark beetles (Scolytidae) IV. *Coleopterists' Bull.* 14: 5-12.

Trägårdh, I. 1905. Acariden aus Ägypten und dem Sudan. *In* L. A. Jagerskiöld, (ed.), Results of the Swedish Zoological Expedition to Egypt and the White Nile 1901, Part 2(17): 1-124; 6 pl.

Vitzthum, H. 1921. Acarologische Beobachtungen, 5. Reihe. *Arch. f. Naturg.* 87, Abt. A, Heft 4: 1-77.

(Received March 10, 1961)

A New Subgenus and Species of *Toxopterella* Hille Ris Lambers (Homoptera : Aphididae), from *Sorbus*[1]

By M. E. MacGillivray[2] and G. A. Bradley[3]

Hille Ris Lambers (1960) erected the genus *Toxopterella* for his new species, *canadensis*, collected in Ontario and New Brunswick from *Crataegus*. At that time he had seen only the alate form of the species from *Sorbus* described herein, not the fundatrix, which is almost indistinguishable from the fundatrix of *Toxopterella canadensis* H.R.L. Because of the similarities in the fundatrices and because of the unique characters that they have in common in this morph, we place the aphid from *Sorbus* in the genus *Toxopterella* H.R.L., 1960. But the alatae of the two species are distinctly different and we therefore place this species from *Sorbus* in a new subgenus *Sorbobium*.

[1]Contribution No. 56, Research Station, Canada Department of Agriculture, Fredericton, New Brunswick, and No. 791, Forest Biology Division, Department of Forestry, Ottawa.

[2]Entomology and Plant Pathology Section, Research Station, Research Branch, Canada Department of Agriculture, Fredericton. New Brunswick.

[3]Forest Biology Laboratory, Winnipeg, Manitoba.

Subgenus *Sorbobium*, new subgenus, differs from *Toxopterella* H.R.L. sensu stricto in the fundatrix by the shape of the cauda and by the six-segmented antennae. In other respects the fundatrices are almost identical. In the alate form of *Sorbobium* there are no sound pegs on the hind tibiae, the first joints of the tarsi have three hairs or sometimes those of the hind tarsi have two hairs, the cauda is not finger-shaped, and the media of the fore wing is twice-branched.

***Toxopterella (Sorbobium) drepanosiphoides*, new species**

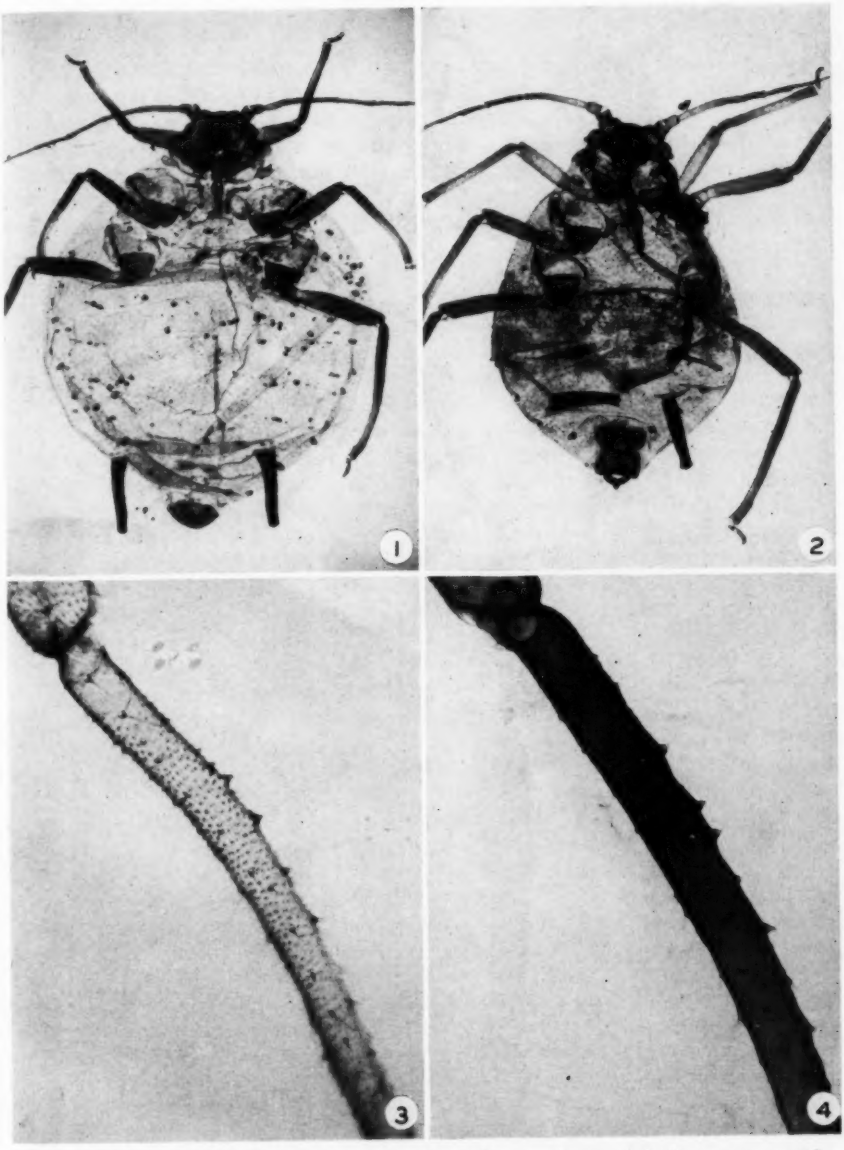
Fundatrix (Fig. 1)

Colour in life purplish-black. Body ventrally flat, dorsally strongly convex, almost semiglobular; broadly oval, 3.68 to 3.83 mm. long. Tergum with small, transverse, blackish-brown, granular, pleuro-marginal intersegmental sclerites; with a pair of spinal and pleural intersegmental sclerites between segments three and four; and a pair of pleural intersegmental sclerites between segments four and five. Integumentum faintly pigmented, with the head, stigmal plates, cauda, subanal and subgenital plates blackish. Tergum rough, densely covered with blunt or flat-topped nodules. No marginal or spinal tubercles present. Dorsal hairs very numerous, thin and wavy, acute, up to 0.075 mm. long. Head densely covered with small, blunt spinules; frons slightly convex in the middle. Antennae of six segments; about one-half of length of body; the same colour as the head with segments one to four covered with small blunt scales, the rest normally imbricated; antennal hairs like the dorsal hairs on the body, longest hair on third segment up to two times diameter of that segment at its constricted base. Rostrum reaching second coxae; basal segments with irregularly arranged lines of spinules; last segment 0.14 to 0.16 mm. long with two to three hairs besides the subapical three pairs. Siphunculi deep black, gradually tapering from base to apex, densely imbricated, with imbrications irregularly serrated. Cauda short and broad, parallel-sided near base, bluntly triangular on distal two-fifths part; with 13 to 22 rather long hairs. Legs the same colour as the head; coxa, trochanter, femur and tibia very spinulose and with long hairs like those on the dorsum; on the thicker basal one-half to two-thirds of inner side of hind tibia an irregular row of seven to 15 short, blunt sound pegs; first tarsal joints with two hairs; second joint of hind tarsus 0.11 to 0.13 mm. long.

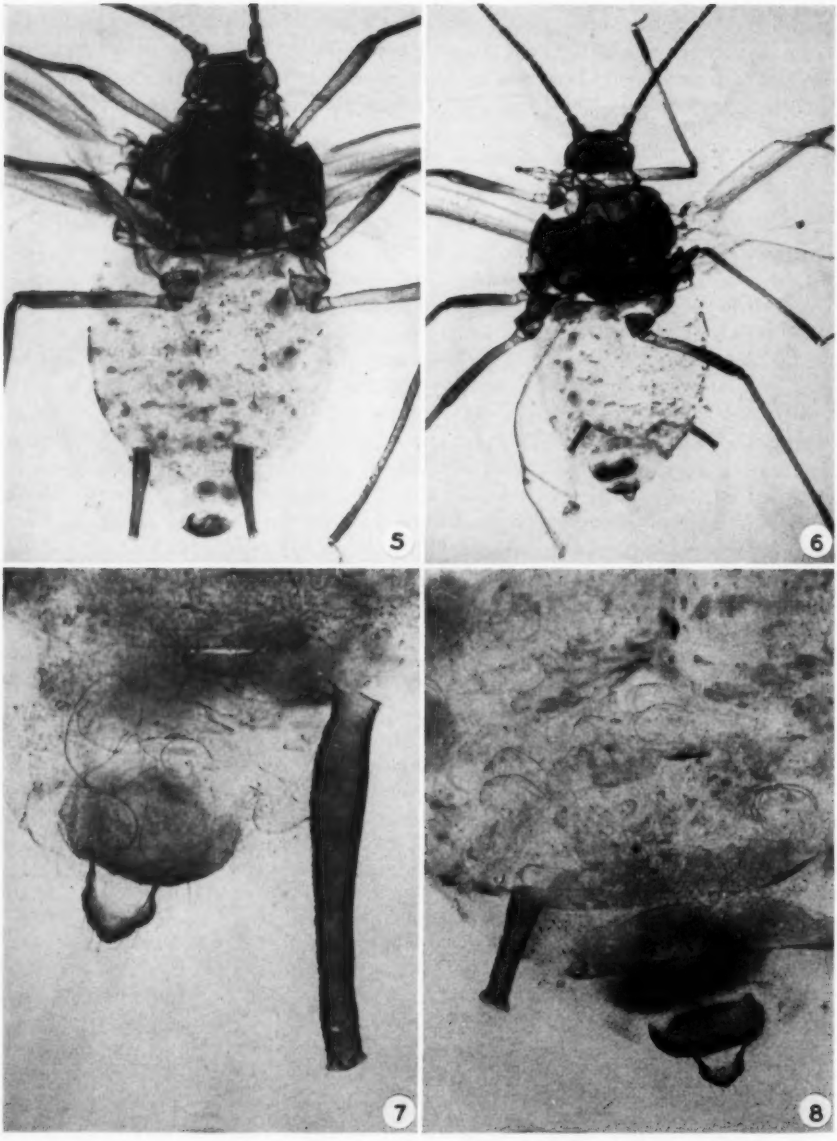
Measurements in mm.

No.	Length body	Ant.	Siph.	Cau.	Ant. segments			
					III	IV	V	VI
1	3.79	1.83	0.66	0.14	0.35	0.33	0.33	0.27+0.34
2	3.82	1.87	0.68	0.14	0.36	0.34	0.35	0.29+0.32
3	3.71	1.88	0.68	0.15	0.36	0.32	0.33	0.30+0.38
4	—	1.74	0.64	—	0.33	0.32	0.34	0.25+0.32
5	—	1.57	0.68	—	0.36	0.29	0.27	0.21+0.24
6	3.68	1.97	0.71	0.15	0.39	0.34	0.36	0.30+0.35
7	—	1.51	0.57	0.12	0.54	—	0.29	0.23+0.25
8	3.80	1.77	0.64	0.15	0.34	0.34	0.35	0.25+0.32
9	—	1.89	0.69	—	0.36	0.37	0.36	0.26+0.35
10	3.83	1.93	0.73	0.16	0.44	0.33	0.37	0.26+0.35

(1-10, from *Sorbus americana* (Marsh.), St. Quentin-Nictau Road, N.B., G. E. Estabrooks, 19-VI-1959).



Figs. 1-4. 1. Fundatrix, *Toxopterella* (*Sorbobium*) *drepanosiphoides*, new species. 2. Fundatrix, *Toxopterella* (*Toxopterella*) *canadensis* H.R.L. 3.Sound pegs on hind tibia of immature alate female of *Toxopterella* (*Sorbobium*) *drepanosiphoides*, new species. 4. Sound pegs on hind tibia of fundatrix of *Toxopterella* (*Toxopterella*) *canadensis* H.R.L.



Figs. 5-8. 5. Alate viviparous female, *Toxopterella* (*Sorbobium*) *drepanosiphoides*, new species. 6. Alate viviparous female, *Toxopterella* (*Toxopterella*) *canadensis* H.R.L. 7. Cauda and siphunculus of *Toxopterella* (*Sorbobium*) *drepanosiphoides*, new species. 8. Cauda and siphunculus of *Toxopterella* (*Toxopterella*) *canadensis* H.R.L.

Morphotypes, fundatrix, No. 7524, in the Canadian National Collection of Insects, Ottawa, Canada.

Nymphs

The very young nymphs are similar to the fundatrix in the shape of the siphunculi and cauda. Older nymphs in which the wing pads are developed and in which traces of rhinaria can be seen on the antennae have the siphunculi densely covered with scale-like groups of one to three very sharp spinules and shaped like the adult alate female. In these older nymphs three hairs could be seen on the first joint of the hind tarsus. In all the nymphs examined the sound pegs (Fig. 3) were present on the hind tibiae. Embryones in the alatae seem also to have the sound pegs and exceptionally rough hind tibiae.

Alate viviparous female (Fig. 5).

Colour in life brown, nymphs light brown. Body 2.07 to 2.72 mm. long. Head and thorax black; abdominal tergum membranous, hardly pigmented; abdomen with very pale brownish, large, marginal sclerites on segments two to four, and darker brown, small, usually paired pleural intersegmental spots and in most specimens each of segments one to six with rather vague, brownish, irregular, often broken transverse bars; sclerotic pattern variable depending on the age of the insect. Head rather smooth, only slightly scabrous on the hardly developed antennal tubercules. Hairs on vertex rather short, about 0.015 mm. long, rather blunt. Antennae of six segments; subequal in length to body or longer; segments one and two and base of three scabrously imbricated, with the apex of segment five and all of segment six distinctly imbricated, remainder of flagellum faintly imbricated; antennae the colour of the head, usually evenly pigmented except for segment six which may be paler; flagellum with tuberculate, transversely oval rhinaria, segment three with 32 to 53, and segment four with 19 to 38 all around the segments, segment five with 10 to 28 scattered rhinaria which may extend the length of the segment, primary rhinaria without hairy fringe; longest hairs on segment three one-half to two-thirds of basal diameter of that segment, blunt. Rostrum surpassing first coxae; basal segments denticulate; last segment with two to four hairs besides the apical three pairs, 0.10 to 0.12 mm. long. Siphunculi rather scabrously imbricated (Fig. 7) but on basal two-thirds on outer side over about two-thirds of their circumference, smooth or almost smooth; usually strongly constricted at base, rather abruptly swelling up to 1.6 times basal diameter then gradually narrowing to the nearly cylindrical distal half; flange not much developed, up to 1.3 times as wide as the portion just basad. Cauda dark sclerotic, with 7 to 14 hairs; nearly as long as wide; knobbed, basal one-third part more or less tapering forming a neck, then suddenly widening so that at the middle of the cauda the width is sometimes 1 2/7 times as wide as the neck, the distal one-half portion rather strongly tapering to the blunt apex. Legs brown, rather evenly, darkly, pigmented, but middle portion of tibia may be paler; coxa and femur dorsally and ventrally spinulose; tibiae without sound pegs, not spinulose, but dorsally slightly wrinkled, with short, acute hairs; first tarsal joints with three hairs, with the middle hair longer and stouter than the lateral hairs, sometimes first tarsal joints of hind tibiae with two hairs. Wings hyaline, with the veins rather dark brown, slightly bordered with brown; venation normal with second branch of media close to the margin of the wing.

Measurements were made of seventy-three specimens. The measurements of ten specimens from each of three samples and the average measurements of all the specimens examined are given in the following table.

Measurements in mm.

No.	Length body	Ant.	Siph.	Cau.	Rhinaria on segments			Ant. segments			
					III	IV	V	III	IV	V	VI
1	2.37	2.36	0.52	0.11	33&38	29&32	12&16	0.46	0.41	0.44	0.28+0.62
2	2.47	2.39	0.54	0.11	36&39	29&33	23&28	0.47	0.39	0.46	0.27+0.63
3	2.44	2.45	0.51	0.11	43&48	29&32	19&21	0.52	0.37	0.41	0.27+0.71
4	2.68	2.47	0.51	0.11	48&50	29&38	23&24	0.51	0.41	0.45	0.27+0.68
5	2.57	2.32	0.52	0.10	33&36	30&35	17&23	0.46	0.39	0.44	0.25+0.61
6	2.72	2.43	0.54	0.12	37&43	34&34	20&23	0.45	0.37	0.43	0.27+0.72
7	2.70	2.45	0.54	0.11	45&48	31&32	15&25	0.52	0.35	0.43	0.27+0.70
8	2.45	2.44	0.52	0.11	39&41	27&27	19&20	0.51	0.36	0.42	0.25+0.73
9	2.55	2.39	0.51	0.11	44&48	31&31	17&20	0.48	0.36	0.38	0.27+0.74
10	2.44	2.38	0.51	0.11	36&40	28&29	17&17	0.45	0.35	0.45	0.27+0.71
11	2.51	2.34	0.51	0.11	37&37	27&27	16&17	0.45	0.37	0.41	0.26+0.68
12	2.32	2.41	0.51	0.11	39&39	27&28	16&17	0.51	0.35	0.42	0.24+0.74
13	2.50	2.28	0.51	0.11	32&38	25&26	17&19	0.41	0.35	0.38	0.23+0.74
14	2.38	2.41	0.51	0.11	42&45	29&32	22&24	0.47	0.39	0.42	0.27+0.68
15	2.28	2.33	0.51	0.11	44&45	27&27	17&19	0.50	0.34	0.43	0.26+0.65
16	2.07	2.18	0.47	0.11	43&45	28&32	20&23	0.43	0.33	0.39	0.25+0.62
17	2.24	2.23	0.50	0.11	38&43	28&30	15&20	0.45	0.34	0.41	0.21+0.65
18	2.26	2.37	0.50	0.11	41&44	31&36	18&23	0.48	0.36	0.43	0.28+0.65
19	2.14	2.27	0.47	0.10	39&43	26&27	14&14	0.46	0.36	0.41	0.26+0.62
20	2.63	2.30	0.54	0.11	39&40	29&29	14&20	0.47	0.38	0.38	0.24+0.65
21	2.47	2.53	0.51	0.11	46&47	29&30	16&19	0.52	0.36	0.43	0.24+0.81
22	2.64	2.51	0.56	0.11	43&47	30&31	11&20	0.52	0.36	0.43	0.25+0.80
23	2.63	2.54	0.52	0.10	48&52	27&30	19&20	0.53	0.38	0.42	0.24+0.80
24	2.53	2.53	0.53	0.11	43&44	31&31	15&17	0.52	0.37	0.44	0.24+0.79
25	2.47	2.68	0.54	0.10	43&46	26&34	15&20	0.56	0.39	0.45	0.26+0.83
26	2.43	2.57	0.51	0.10	35&42	26&28	14&20	0.51	0.39	0.46	0.24+0.79
27	2.47	2.65	0.56	0.09	39&42	31&31	19&21	0.54	0.38	0.45	0.27+0.82
28	2.61	2.62	0.52	0.10	45&47	26&26	15&19	0.53	0.38	0.46	0.24+0.82
29	2.56	2.56	0.56	0.10	48&51	27&31	22&22	0.52	0.38	0.45	0.24+0.80
30	2.47	2.33	0.55	0.10	42&45	32&32	16&20	0.51	0.34	0.43	0.23+0.66

(1-20, from *Sorbus americana* Marsh, 10-12 miles north-east on Stewart Highway, N. B., G. E. Estabrooks; 1-10, 15-VII-1958; 11-20, 8-VII-1959; 21-30, from *Sorbus sitchensis* Roem., Legate Creek, B. C., S. J. Allen, 19-VII-1955).

Average measurements with standard error: Length of body: 2.46±0.016 mm.; antenna: 2.43±0.017 mm.; siphunculus: 0.52±0.003 mm.; cauda: 0.11±0.003 mm. Antennal segments: $\frac{0.48\pm0.004}{\text{III}}$; $\frac{0.37\pm0.003}{\text{IV}}$; $\frac{0.43\pm0.003}{\text{V}}$; $\frac{(0.26\pm0.002)+(0.71\pm0.001)}{\text{VI}}$ mm. Rhinaria on antennal segments: $\frac{41.6\pm0.38}{\text{III}}$; $\frac{30.0\pm0.31}{\text{IV}}$; $\frac{19.3\pm0.32}{\text{V}}$.

Holotype.—Alate viviparous female, 10 to 12 miles northeast on Stewart Highway, N.B., 15-VII-1958 (G. Estabrooks). No. 7524, in the Canadian National Collection of Insects, Ottawa, Canada.

Paratypes.—Alate viviparous females, 10 to 12 miles northeast on Stewart Highway, N.B., (G. Estabrooks); thirty-two alate viviparous females from same collection as holotype, 15-VII-1958; twenty-eight alate viviparous females, 8-VII-1959. No. 7524, in the Canadian National Collection of Insects, Ottawa, Canada.

Notes.—Alatae of this species were first encountered by one of us (G.A.B.) in a collection from *Sorbus sitchensis* Roem., Legate Creek, B.C., 19-VII-1955 made by S. J. Allen. The other author (M.E.M.) found alatae in a forest insect survey collection, 58-0874 made in New Brunswick in 1958 by G. Estabrooks. In 1959 *Sorbus americana* on the Stewart Highway in the Northern part of New Brunswick was carefully checked from early June until the fundatrices and alatae

appeared. The fundatrices were collected from rather tightly curled leaves; one compound leaf made up the curl. Each curl contained one fundatrix and its progeny. Only with difficulty could the nymphs be reared to maturity on fresh leaves.

The life history of the species on *Sorbus* appears to be rather simple. The fundatrices were mature by June 16 in 1959 and so possibly hatched in late May or early June. The first generation is winged and is mature in early July, and has left *Sorbus* by late July. Attempts were made to transfer the alatae to several plants in a wide range of families but the alatae did not colonize any plants presented to them including various mosses, sedges, and Umbelliferae.

It is remarkable that the two species of *Toxopterella* with such unique characters and whose life histories are unknown should be discovered within such a short time of one another. Also if the fundatrix of *Toxopterella* (*Sorbobium*) *drepanosiphoides* had not been discovered it is unlikely that the alatae at this time would have been placed in the same genus as *T. canadensis* H.R.L. Although the fundatrices of the two species might be confused, *T.* (*Sorbobium*) *drepanosiphoides* can be separated in this morph from *T. canadensis* (Fig. 2) by the shape of the cauda and by its larger size. The alatae (Figs. 5, 6) can be readily distinguished from each other by the shape and length of the siphunculi, (Figs. 7, 8) and by the wing venation.

Acknowledgments

The authors wish to acknowledge the assistance of Ranger S. J. Allen, Forest Biology Laboratory, Victoria, B.C., who collected the first specimens in Canada in 1955, and Ranger G. F. Estabrooks, Forest Biology Laboratory, Fredericton, N.B., who collected the first specimens in New Brunswick in 1958 and who made special collections in 1959. Also we wish to thank Mr. D. Hille Ris Lambers, Bennekom, Netherlands, for his helpful criticism of the manuscript.

Reference

Hille Ris Lambers, D. 1960. Some new genera and species of aphids from Canada (Homoptera : Aphididae). *Canadian Ent.* 92: 251-263.

(Received February 21, 1961)

The Life History of *Aptesis basizona* (Grav.) on *Neodiprion sertifer* (Geoff.) in Southern Ontario[1]

By K. J. GRIFFITHS

Forest Insect Laboratory, Sault Ste. Marie, Ontario

Introduction

Aptesis basizona (Grav.) is a common and widely distributed parasite of diprionid sawflies in central, western, and northern Europe, with parasitism varying from three to 90 per cent on different hosts and in different areas. One of these sawflies, *Neodiprion sertifer* (Geoff.), is very commonly attacked, with parasitism of 30 to 80 per cent in Czechoslovakia, 10 to 52 per cent in Hungary, and 17.5 to 40 per cent in Sweden (Morris *et al.*, 1937).

The parasite has had a brief history in Canada, dating from 1933. It was collected in large numbers in Europe between 1933 and 1936 for release against the European spruce sawfly, *Diprion hercyniae* (Htg.), in the Maritime Provinces and Quebec (Morris *et al.*, 1937; Finlayson and Reeks, 1936; Reeks, 1953).

[1]Contribution No. 767, Forest Entomology and Pathology Branch, Department of Forestry, Ottawa, Canada.

From 1938 to 1946 the species was released in Ontario in an attempt to establish it on various introduced and native sawflies, including *N. sertifer* (Baird, 1947). It was recovered in 1941, 1946, and 1947 in very small numbers at or near release points (Finlayson and Finlayson, 1958), but was not obtained from 1953 to 1956 by Griffiths (1959), who made collections at one of the release points, Strathroy, Ontario, and at several other localities within 40 miles of Strathroy. In 1958, it appeared in small numbers in cocoon collections from a plot near Chatsworth, Ontario, some 50 miles from the nearest known release point, which is Angus, Ontario (Baird, 1947). Parasitism of cocoons from this plot increased in the next two years to the point where *A. basizona* promised to become of some importance as a mortality factor of cocoon populations of *N. sertifer*. This introduced sawfly is the subject of a comprehensive study in the Chatsworth area, and the following account of the life history of *A. basizona* is a contribution to our knowledge of its role in the population dynamics of its host, *N. sertifer*, in southern Ontario.

Methods

Most of the work was carried out near Chatsworth, Ontario, in an unheated laboratory where temperature conditions paralleled those outdoors. Rearings of *A. basizona* were started with adults obtained from field-collected sawfly cocoons. The parasite adults were kept for observations of oviposition and behaviour in glass rearing jars, containing host cocoons dispersed in vermiculite. Dissection of these cocoons provided parasitized hosts for development studies. The exposed host prepupae were reared in glass tubes of approximately the same inside diameter as host cocoons, permitting daily microscopic examination without disturbance to the developing parasites. Mortality under this treatment was negligible. At the end of the field season, individuals that had not completed development were placed in cold storage (two weeks at 42°F, 12 weeks at 32°F) and then brought to room temperature and examined daily until maturity.

The seasonal course of parasitism was studied by exposing *N. sertifer* cocoons to attack in the field. Fifty cocoons were placed in each of eight wooden trays, which were set out in the litter in a red pine plantation, four in shaded situations, and four in sunny situations. The cocoons were protected from predation by coarse-mesh wire screening placed on top and bottom of the trays. Four trays were set out on June 18 and four on June 23, and they remained undisturbed until November 2, but the cocoons in them were replaced every ten days. About 4,750 cocoons were exposed to attack during the field season. Cocoons removed from trays were checked daily for parasite emergence throughout the summer and again after three months in cold storage.

Results

The adult emerges from the end of the host cocoon through a circular opening approximately 2 mm. in diameter. Mating takes place immediately after emergence and lasts less than a minute. The process has been briefly described by Morris *et al.* (1937). Mated females produce offspring of both sexes, but reproduction may occur by arrhenotoky.

Twenty-four adults lived an average of eight days, ranging from four to 14 days, in captivity. There was no sex difference in the adult life span. This is considerably shorter than the life-span in captivity of 40 to 50 days reported by Green (1938).

When searching for cocoons in the experimental containers the adult female holds her antennae parallel to the substrate, at right angles to each other, with

the tips bent downward and almost touching the ground. They are continually vibrating and "exploring" the substrate in front of the female. When a cocoon is touched, the angle between the antennae is lessened and the antennae are laid along or around the cocoon. Occasionally the surface of the cocoon, including the undersurface, is caressed with the antennae. The female then mounts the cocoon and spends some time alternately tapping it with her ovipositor and examining it with her antennae, sometimes interrupted by a period of antennae-cleaning. The ovipositor is then inserted to approximately half its length. With the ovipositor in this position, the female makes occasional jerky movements, suggesting disturbance from movements of the host. Later the ovipositor is inserted more deeply, or it may be removed and a second, deeper, insertion made at another site. The ovipositor is left within the host for some time, in one case for two hours and 40 minutes. When it is removed, the female cleans her antennae and leaves the cocoon.

On the first insertion of her ovipositor, the female apparently paralyses the host, since hosts were usually immobile when examined after attack. Prepupae paralysed by *A. basizona* usually bear the mark of the parasite's ovipositor on their body. The injured area generally consists of a dark brown central spot, surrounded by an area of lighter brown, and an outer dark brown circle. The area measures 0.2 mm. in diameter. Its shape is frequently distorted and sometimes it is absent even though an egg has been laid. Injury of prepupae from the parasite's ovipositor occurred on the ventral surface in 60 per cent of 45 observed cases and on the lateral surface in the remainder. Marks were found on all body segments, and on one occasion, on the epiproct. In the latter case, the broken tip of the parasite's ovipositor remained inserted in the integument.

The parasite occasionally paralyses its host without depositing an egg. In only one of 13 such cases observed did the host become an adult. In the other instances the host died, either without any further development, or after attaining the early pronymphal phase.

Most hosts were attacked in the eonymphal stage and only 10 per cent were in the very early pronymphal stage. Eggs were never found in cocoons containing advanced pronymphs or pupae.

The egg is laid externally, and is generally found loose in the cocoon. Morris *et al.* (1937) observed the oviposition on one host and noted that the egg was "lightly attached" to the thoracic pleural region. This may be the normal procedure, the egg being dislodged when the host is removed from the cocoon.

Morris *et al,* (1937) described the egg as white and opaque, somewhat subreniform in shape with the micropylar end tapering more acutely. This agrees with the present findings except that occasionally yellowish eggs were found. According to measurements made in this study deposited eggs are 1.23 mm. long (range 1.12 to 1.35 mm.) and 0.34 mm. wide at the widest point (range 0.27 to 0.41 mm).

The egg capacity of *A. basizona* females is low. Four of the five adults dissected within 24 hours of emergence had no mature eggs in their ovaries, and contained only one to three eggs approximately half the size of mature eggs. The ovaries of 11 older adults, ranging from two to nine days in age, contained an average of 3.8 mature eggs and 3.6 half-formed eggs. The greatest number of mature eggs found in any female was eight. These observations indicate that a pre-oviposition period of at least one day is necessary before oviposition can start. Ovarian eggs are smaller than deposited eggs, averaging 0.92 mm. long and 0.24 mm. wide, indicating that they swell considerably after oviposition.

Superparasitism occurred occasionally in laboratory-parasitized prepupae, as many as four eggs being found in a single cocoon. This results in wastage of eggs, since only one larva reaches maturity on one host. In four hosts, each with more than one egg, only one hatched and developed. In three others two or more eggs hatched and all but one of the larvae died with some appearance of damage. In one case both eggs hatched, with both larvae dying in the first instar.

The incubation period of 20 eggs under observation was two days. Larvae feed externally, and the larval period (to the beginning of cocoon spinning) averaged nine days with a range of seven to 10 days. The variation in this period appeared to bear no relation to the season's advance, since as many of the 24 observed larvae required 10 days to develop in mid-August as in mid-September. The average duration of the five instars was as follows: First instar, three days, occasionally two or four days; second instar, one day, rarely two; third, fourth and fifth instars, usually two days. This rate of development was much faster than that reported by Morris *et al.* (1937), who found that larval development required from 13 to 15 days. The difference lies in the final four instars, each of which averaged one day longer in their study.

The first and second instars are unique among *N. sertifer* parasites in that the head is equal to or greater in width than the rest of the body and bears conspicuous antennae. These distinguishing characters are not present in the remaining three instars. A description of the first and last instars has been given by Morris *et al.* (1937).

Increase in size, as indicated by total length measurements, was very rapid. The larvae, which averaged 1.26 mm. long on the first day, nearly doubled their length every three days. The average length on the last day before cocoon spinning was 8.36 mm. By this time the host is reduced to a shrivelled skin.

After the end of the feeding period, the larva spins a rather flimsy whitish cocoon within the host cocoon, but excluding the host remains. After cocoon-spinning some of the population continued development to produce a second generation, and some went into diapause. The eonymphal period of the non-diapause stock, lasted an average of three days from the beginning of cocoon spinning. The brownish, bead-like meconium was cast on the second day. The pronymphal period, its beginning indicated by the first appearance of the imaginal eye, and subsequently characterized by the constriction of the thorax from the abdomen, averaged one and one half days. The pupal period lasted an average of eight days, and the total developmental time, from egg-laying to adult emergence, was 23 days. The diapause stock did not resume development until the following spring. The inception of diapause did not appear to be associated with advancement of the season. For example, all six eggs laid by one female on August 24 hatched and developed to the eonymphal stage but four of them overwintered in this stage. The other two, as well as eight other eggs laid by this female in the following five days, developed to the adult stage without evidence of diapause.

Prepupae of the diapause stock cast their meconium an average of three days after removal from overwintering quarters, and commenced the pronymphal phase four days after removal. This phase lasted one day, the pupal period nine days. The total developmental period to adult averaged 14 days after removal from cold storage.

The recovery of *A. basizona* adults from cocoons set out in trays throughout the season showed that this species is active during most of the summer (Fig. 1). Adults emerged from cocoons in only one of the first group of trays set out on

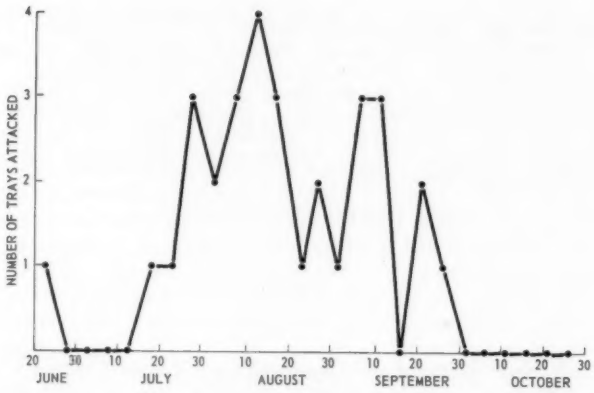


Fig. 1. Attack of *A. basizona* on *N. sertifer* in the field, based on exposure of trays of cocoons for 10-day periods. The number of trays attacked during each exposure period is shown as though it occurred at the mid-point of the period.

June 18. They were not obtained from cocoons throughout the remainder of June and up to mid-July, but were present in one or more of the trays from then to the end of September. The number of trays from which adults were obtained increased from mid-July to mid-August. Parasitism then dropped off and the last parasites were obtained from trays exposed from September 21 to 28. If the insect requires the same length of time to complete a generation in the field as in the laboratory, then three or more generations may have occurred in this period. Females searched equally diligently for cocoons in exposed and shaded sites, since there was no statistical difference in the number of attacks on cocoons in trays in these two types of habitat.

Up to mid-August, all parasites developed directly to the adult. From that date on, however, approximately half remained in the host cocoon overwinter, emerging after cocoons were removed from cold storage in the spring.

Summary

A. basizona, a parasite of some importance on diprionids in Europe, was introduced into Canada against various sawflies a number of years ago. It was recently found to be attacking *N. sertifer* in southwestern Ontario in considerable numbers. It is a multivoltine ectoparasite and attacks the eonymphal and early pronymphal phases of the prepupal stage of its host. It requires approximately three weeks to complete a generation. Towards the end of the summer a portion of the population stops development at the eonymphal phase and overwinters. Others which start development at the same time continue right through to the adult. Parasitism occurred in the field from late June to the end of September, with a peak of activity in mid-August.

References

Baird, A. B. (Editor). 1947. Control of forest insects in the province of Ontario by introduction of insect parasites. A brief prepared at the request of the Ontario Royal Commission on Forestry.

Finlayson, L. R., and T. Finlayson. 1958. Parasitism of the European pine sawfly, *Neodiprion sertifer* (Geoff.) (Hymenoptera: Diprionidae), in southwestern Ontario. *Can. Ent.* 90: 223-225.

Finlayson, L. R., and W. A. Reeks. 1936. Notes on the introduction of *Diprion* parasites to Canada. *Can. Ent.* 68: 160-166.

Green, T. U. 1938. A laboratory method for the propagation of *Microcryptus basizonius* Grav. *69th Ann. Rep. Ent. Soc. Ont.* 32-34.
Griffiths, K. J. 1959. Observations on the European pine sawfly, *Neodiprion sertifer* (Geoff.), and its parasites in southern Ontario. *Can. Ent.* 91: 501-512.
Morris, K. R. S., E. Cameron, and W. F. Jepson. 1937. The insect parasites of the spruce sawfly (*Diprion polytomum* Htg.) in Europe. *Bull. Ent. Res.* 28: 341-393.
Reeks, W. A. 1953. The establishment of introduced parasites of the European spruce sawfly (*Diprion hercyniae* (Htg.) (Hymenoptera: Diprionidae) in the Maritime provinces. *Can. J. Agr. Sci.* 33: 405-429.

(Received May 31, 1961)

A New Record of *Leptinillus validus (Horn)* (Coleoptera: Leptinidae) in North America[1]

By R. C. CLARK
Forest Biology Laboratory, Fredericton, New Brunswick

In November, 1957, several specimens of adult beetles were collected from beaver pelts taken in the Lake George area of New Brunswick by a local trapper, Mr. Donald Millican. These were referred to me and were later identified as *Leptinillus validus* (Horn), an ectoparasite of the beaver, *Castor canadensis* Kuhl, by Mr. W. J. Brown of the Entomology Research Institute, Ottawa. This is the first record of the species having been found in New Brunswick.

Parks and Barnes (1955) record the collection of a small number of adults of this species in Minnesota in 1955, and previous collections by others from Hudson Bay, N.W.T., Quebec, Ontario, British Columbia, and the states of Alaska and Maine, U.S.A. Bailey (1923) recorded the species from Wisconsin. The collections from Quebec and Maine were made considerably north and west, respectively of the New Brunswick border.

Additional collections have been made by Mr. Millican in the same general area; one adult in November 1958, and five adults and 18 larvae in November 1960. He reports that in all cases the specimens were taken from the fur of the beaver, about 24 hours after removal of the animals from the traps in the water. Both larvae and adults were very active and difficult to collect. There was no apparent damage to the pelts, suggesting that both adults and larvae probably feed on dermal scales and other skin debris.

Wood (1959) has recently completed an extensive study of this species and the more common *Platypsyllus castoris* Ritsema in Algonquin Park, Ontario.

References

Bailey, V. 1923. The combing claws of the beaver. *J. Mammal.* 4: 77-79.
Parks, James J., and John W. Barnes. 1955. Notes on the Family Leptinidae including a new record of *Leptinillus validus* (Horn) in North America (Coleoptera). *Ann. Ent. Soc. Amer.* 48(5): 417-421.
Wood, Donald M. 1959. Studies on the beetles *Leptinillus validus* (Horn) and *Platypsyllus castoris* Ritsema (Coleoptera: Leptinidae) from beaver. Thesis submitted for degree of Master of Arts, University of Toronto, Ontario. (Unpublished)

(Received May 3, 1961)

[1]Contribution No. 753, Forest Entomology and Pathology Branch, Department of Forestry, Ottawa, Canada.

Immature Stages and Biology of *Hyperplatys* spp. (Coleoptera: Cerambycidae) in Eastern Canada[1]

By L. M. GARDINER
Forest Insect Laboratory, Sault Ste. Marie, Ontario

The lamiine genus *Hyperplatys* Haldeman is represented in Eastern Canada by two species, *H. maculata* Hald. and *H. aspersa* (Say). Both are small, greyish long-horned beetles with spotted elytra. These species have suffered from considerable taxonomic confusion, having been misdetermined by Blatchley (1910), Felt (1924), Knull (1946), and probably a number of other authors. Craighead (1923) described the larva and pupa of *H. asperus* Say (sic), but apparently this was also a misdetermination, since his pupal description obviously refers to *H. maculata*.

Current studies of Cerambycidae at Sault Ste. Marie have produced new information on the immature stages and biology of the Canadian species. The immature stages described here are in the Cerambycid Collection at Sault Ste. Marie under the following numbers: *H. aspersa*, LA17.1.2, LA17.1.4; *H. maculata*, LA17.2.1, LA17.2.2.

Descriptions of Immature Stages
Hyperplatys maculata Haldeman

Advanced Larva

Length up to 11.5 mm., width of prothorax 1.8 mm.

Head depressed, rather ovate, sides curved and converging posteriorly (Fig. 1); mouthframe only lightly sclerotized; epistoma with six stout setae; mid-cranial sulcus indistinct over much of its length; frontal sutures indistinct but traceable, bisecting antennal sockets; frons bearing a transverse, regular row of 10 uniform setae, the setae at each end set caudad of the general line; epicranial halves bearing lateral, longitudinal rows of four short setae arising behind frontal sutures; posterior margin of head strongly rounded. Genae bearing three or four stout setae; one pair of ocelli; antennae three-segmented, second segment transverse, third conical, supplementary about half the length of third. Hypostoma bearing four long setae; gula reduced to a median suture.

Labrum broader than long, uniformly rounded from base, anterior half densely beset with short setae; mandibles divided into basal and distal portions, the latter strongly curved and acute, almost bidentate (Fig. 2); basal part bearing two setae on outer face.

Ventral mouthparts fused basally, forming a broad connection to the mouth-frame; maxillary palpi slender, last joint longer than second, shorter than first; slightly shorter than last labial; ligula broad; mentum distinct, transverse.

Prothorax trapezoidal, tapering anteriorly, clothed with fine, light brown hairs on lateral regions. Anterior half of pronotum shining, lightly sclerotized, a line of fine hairs across anterior margin; posterior half velvety spiculate. Mesonotum granulate; metanotum tuberculate. Prosternum rugose and granulate; eusternum poorly defined. Meso- and metasterna bearing two rows of distinct tubercles. Legless.

Dorsal abdominal ampullae tuberculate, with two irregular rows of tubercles, for the most part broken into two groups, one on either side of the midline. Epipleuron protuberant on last three segments. Spiracles small, orbicular.

[1]Contribution No. 754, Forest Entomology and Pathology Branch, Department of Forestry, Ottawa, Canada.

Pleural tubercles diamond-shaped, width greater than length (latter measured between pits (Fig. 3)).

First Instar

Head more rounded posteriorly than in mature larva, suborbicular from above; frontal setae proportionately much longer; ventral margin of mouthframe indistinct, blending into base of ventral mouthparts; gular suture extending anteriorly to mentum; antennal supplementary process smaller than the terminal joint; ocelli not in evidence. Mandibles, epistoma, and hypostoma unarmed (Fig. 9), unlike a number of other lamiine first-instar larvae.

Setae sparse on labrum, mandible strongly curved distally; ventral mouthparts fleshy, last joint of maxillary palpi longer than basal two, slightly longer than last labial.

Posterior third of pronotum spiculate; second and third thoracic segments with dorsolateral spines (egg-bursting spines of Duffy (1953). Ambulatory ampullae and pleural tubercles undeveloped; dorsolateral spines on first eight abdominal segments. Spiracles biforous (Fig. 10).

Pupa

Head plainly visible from above; lateral margins of vertex and frons marked by a row of prominent spines bearing sub-apical setae (Fig. 4); two similar spines on frons; frons and clypeus separated by an arcuate row of six long, hooked setae.

Anterior margin of pronotum having a row of sparsely placed, acute spines bearing sub-apical setae (Fig. 4). Meso- and metanota shining, glabrous except for a pair of setae at each wing-base. Elytra and hind wings divergent. Hind femora clavate, reaching sixth abdominal segment, bearing a few long setae distally.

Abdomen fusiform, widest at fourth segment. Terga, except first, sparsely armed with very small spines. Seventh tergum armed with an anterior group of small spines, a median line of larger spines, and a posterior group of still larger spines. Eighth tergum bears eight large spines directed mesally. Ninth tergum unarmed, retracted, and barely visible from above. Sterna glabrous, except seventh and eighth which bear a few setae. Functional spiracles present on first six segments.

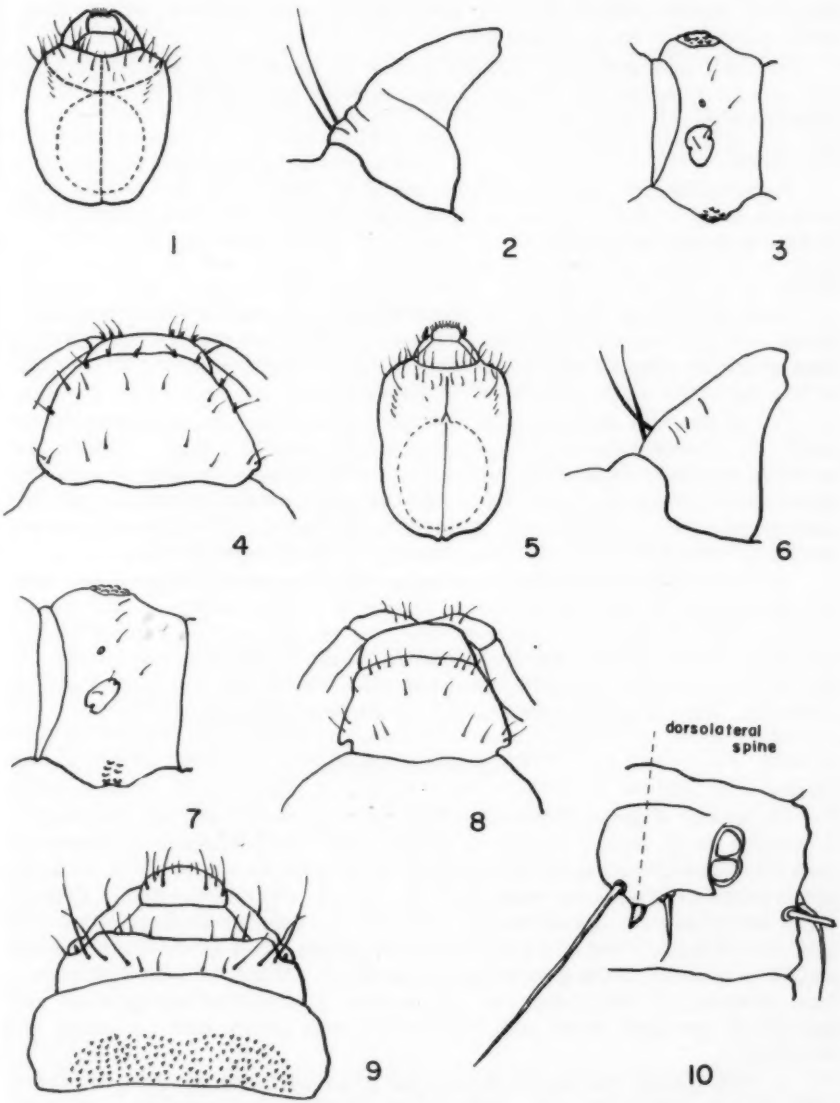
***Hyperplatys aspersa* (Say)**

Advanced Larva

Length up to 7.9 mm., width of prothorax 1.9 mm.

Head depressed, elongate, sides sub-parallel, slightly constricted about middle (Fig. 5); mouthframe strongly sclerotized; epistoma with 6 stout setae; midcranial sulcus distinct; frontal sutures barely traceable except near antennal sockets, which they bisect; frons bearing a transverse row of 10 setae of which the second on each side of the midline is smaller and out of line with the others; epicranial halves bearing lateral longitudinal rows of four short setae; posterior margin of head slightly rounded, marked by a pair of small protuberances at middle. Genae bearing two long and two short setae; one pair of ocelli; antennae three-segmented, second segment cylindrical, sides turned in distally, partially enclosing third segment, supplementary, and other processes. Hypostoma bearing six long setae; gula reduced to a median suture.

Labrum broadly rounded from base, anterior half densely clothed with stiff setae. Mandibles short, stout, not noticeably divided into basal and distal portions, only weakly curved distally; a pair of setae on outer face near base (Fig. 6).



Figs. 1-10. *Hyperplatys* spp. 1-4, *H. maculata*: 1, head of advanced larva; 2, left mandible; 3, abdominal segment showing pleural tubercle; 4, pupal head and pronotum. 5-10. *H. aspersa;* 5, head of advanced larva; 6, left mandible; 7, abdominal segment showing pleural tubercle; 8, pupal head and pronotum; 9, head and pronotum of first-instar larva; 10, dorsolateral spine and biforous spiracle of first-instar larva.

Ventral mouthparts fused basally, forming a broad attachment to the mouthframe; maxillary palpi slender, elongate, all three joints subequal, last maxillary slightly shorter than last labial; ligula broad; mentum distinct, transverse, and strongly rounded laterally.

Thoracic and abdominal features similar to those of *H. maculata*, except that pleural tubercles are oblong, length between pits greater than width of tubercle (Fig. 7).

First Instar

Indistinguishable from that of *H. maculata*, except that the head is more elongate, posterior half of pronotum is spiculate (Fig. 9), and body segments tend to be noticeably compressed.

Pupa

Head prominent from above, unarmed (Fig. 8); vertex glabrous, convex, greatly reduced in width between antennae. Rim of antennal sockets bearing long setae that continue anteriorly along the lateral margins of the frons; other setae along fronto-clypeal sulcus and on mandibles.

Pronotum with straight sides diverging posteriorly to prominent lateral tubercles; a continuous row of long setae along anterior margin. (Meso- and metanota deformed on the only specimen available (right wings undeveloped) but appear to be similar to those of *H. maculata* when normal, except for possible absence of setae). Elytra and hind wings divergent. Hind femora clavate, reaching fourth abdominal segment, bearing a few long setae distally.

Abdomen somewhat flattened, widest at fourth segment. Terga armed with median groups of very small spines, becoming a little larger on the seventh tergum. Eighth tergum with a transverse row of eight incurved spines bearing sub-apical setae. Ninth tergum visible from above, bearing two posteriorly directed spines. Sterna glabrous and unarmed. Ninth sternum with a pair of tubercles. Functional spiracles on first six abdominal segments.

Comparative Biology

Habits

In Simcoe County, Ontario, where the ranges of both species overlap, emergence of *H. aspersa* appears to precede that of *H. maculata* by about one month. The former was found emerging in 1959 on June 2, whereas no emergence of the latter occurred until the first week of July. In the Laniel, Quebec, area, where only *H. aspersa* occurs, emergence usually takes place in late July and early August. The adults are well camouflaged when at rest on their hosts, and drop quickly to the ground when disturbed. Adults of both species have been observed to feed extensively on pustules of *Endothia* sp., growing as a saprophyte on dead stems and branches of host plants such as sumac and butternut.

In both species, the female chews a slit in the bark and, enlarging it slightly with the ovipositor, places the egg under the outer bark some distance from the slit. The eggs, which are laid singly, are elongate, translucent, and slightly over 1 mm. long. In feeding, the larvae of both species excavate an irregular gallery in the inner bark, and a pupal chamber in the wood. A difference has been observed in the manner of feeding by the two species, although it may only be an effect of bark thickness. *H. maculata*, in basswood branches, feeds only in the outer portion of the phloem, then bores straight through the remaining phloem into the wood, to excavate a fairly deep pupal cell. On the other hand,

H. aspersa, in sumac, utilizes the whole thickness of the phloem and even scores the wood surface deeply before boring out a somewhat shallower pupal chamber in the wood. Galleries and entrance holes of both species are left filled with fibrous frass, through which the emerging adult passes. Larvae and pupae taken from the wood have always been found with heads directed towards the entrance to the pupal chamber.

In Ontario and Quebec, one generation per year seems to be the general rule for these species. Both have been observed to reinfest at least once the same host material from which they emerged.

Hosts

Owing to the long history of taxonomic confusion between the species, host records in the literature are completely misleading. Both have been recorded from a large number of hosts (Felt, 1924; Blackman and Stage, 1924), including: oak, cotton-wood, aspen, hackberry, white walnut, sumac, apple, currant, hickory, chestnut, locust, beech, maple, orange, and elm. Reversing Knull's (1946) determinations, we have *H. aspersa* recorded from dead willow branches and *H. maculata* from juneberry.

Observations indicate, however, that *H. maculata* infests a greater diversity of hosts than *H. aspersa*. To date, the latter has been bred only from dead staghorn and smooth sumacs, whereas *H. maculata* has been found in dead branches of red oak, basswood, and butternut. Moreover, *H. maculata* has never been reared from dead sumac, although large quantities of stems and branches from widely separated points in Ontario and Quebec have been caged. Likewise, dead branches of many tree species have never yielded *H. aspersa*.

Distribution

The preceding remarks on the reliability of host records in the literature probably apply, in part at least, to distribution records. It appears, however, that in general the occurrence of *H. maculata* is more southerly than that of *H. aspersa*. Dillon (1956) gives the distribution of *H. maculata* as "the entire eastern half of North America, from Maine south to North Carolina on the Atlantic Coast, west to Missouri and east Texas", and that of *H. aspersa* as "Southern Canada and Northern United States from the Atlantic Coast west to North Dakota and into western Canada to Alberta".

I have found *H. maculata* in Rondeau Park, in Simcoe County, and near Dwight, Ontario (45°20′ N approx.), which appears to extend appreciably the known range of this species. In Ontario, *H. aspersa* has been collected at Pt. Rowan and Minesing in the south, and as far north as Thessalon. Dillon (1946) records it from Thunder Bay. I have also taken this species at Laniel, Quebec (47°00′ N approx.).

Parasites

Muesebeck and Walkley (1951) recorded *H. aspersa* as the host of the braconid *Cenocoelius provancheri* (Rohwer). An apparently undescribed species of the same genus was found in 1957, parasitizing larvae of *H. aspersa* near Laniel. Pupae of this parasite were present in early August in small, flat, hairy cocoons at the end of the borer galleries in sumac. In late July, 1959, cocoons of another braconid were found in *H. aspersa* galleries in the same locality, together with the larval skins of the host. The adults that emerged from the cocoons were submitted to the Entomology Research Institute, Ottawa, where they were identified as *Meteorus tibialis* Mues. According to W. R.

Mason, who identified this and the *Cenocoelius* sp., this is the first time that this species has been reared from any host.

Three sickly larvae of *H. maculata* were taken from dead basswood branches in Simcoe County in late June, 1959. These were sent to D. M. MacLeod, Institute of Insect Pathology, Sault Ste. Marie, who isolated an unidentified green fungus from them. This fungus, which is believed to be entomogenous, was isolated previously from another cerambycid, *Xylotrechus colonus* (Fab.) (Gardiner, 1960), in pure culture and in association with *Isaria farinosa* (Dicks.) Fr.

Summary

Two species of the lamiine genus *Hyperplatys* Haldeman occur in Eastern Canada. Descriptions of their immature stages are given, as well as comparative notes on their habits, hosts, distribution, and parasites. The more northerly species, *H. aspersa* (Say), has been found only in dead sumac, whereas *H. maculata* Hald. infests dead branches of oak, basswood, butternut, and probably a number of other deciduous trees.

References

Blackman, M. W., and H. H. Stage. 1924. I. On the succession of insects living in the bark and wood of dying, dead and decaying hickory. *Tech. Pub. No. 17, N.Y. State Coll. Forestry* 24 (22): 3-269, Syracuse, N.Y.

Blatchley, W. S. 1910. Coleoptera or beetles known to occur in Indiana. *Ind. Dept. Geol. and Nat. Res. Bull.* 1: p. 1078.

Craighead, F. C. 1923. North American cerambycid larvae. *Dom. Can. Dept. Agric. Bull. No. 27—N. S. (Tech.), Ottawa.*

Dillon, L. S. 1956. The nearctic components of the tribe Acanthocinini (Coleoptera: Cerambycidae). Part III *Ann. Ent. Soc. America* 49: 332-355.

Duffy, E. A. J. 1953. A monograph of the immature stages of British and imported timber beetles (Cerambycidae). *British Museum (Nat. Hist.), London.* Jarrold and Sons, Limited, Norwich.

Felt, E. P. 1924. Manual of tree and shrub insects. The MacMillan Co., New York, p. 318.

Gardiner, L. M. 1960. Descriptions of immature forms and biology of *Xylotrechus colonus* (Fab.) (Coleoptera: Cerambycidae). *Canad. Ent.* 92: 820-825.

Knull, J. N. 1946. The long-horned beetles of Ohio (Coleoptera: Cerambycidae) *Ohio Biol. Surv. Bull. 39 (Vol. VII, No. 4)*, Ohio State Univ., Columbus, Ohio.

Muesebeck, C. F. W., and L. M. Walkley. 1951. Family Braconidae. *In* Muesebeck, C. F. W., Krombein, K. V. and H. K. Townes *et al.* 1951. Hymenoptera of America north of Mexico Synoptic Catalog. *U.S.D.A. Agric. Monog. No. 2*, Washington, D.C.

(Received May 3, 1961)

Notes on the Nesting of *Bombus morio* (Swederus) (Hymenoptera: Apidae)[1]

By H. E. Milliron
Entomology Research Institute, Research Branch
Canada Department of Agriculture, Ottawa, Ontario

This bumblebee is rather common in southeastern Brazil, northern Argentina, and in parts of western South America. However, no detailed specific data have yet been published on its biology or nesting habits.

On November 5, 1955, while searching for bumblebees in Brazil, the writer succeeded in finding a newly established nest of this species about one-fourth mile from the coast in Parana, north of Guaratuba near Praia de Leste, some eight miles south of Matinhos. The coastal terrain at that location is somewhat irregular, not exceeding fifty feet in elevation and covered, for the most part, with rather dense, low woody vegetation. Near mid-day, from a vantage point at the side of the only north-south road, I spotted a queen in low direct flight toward a clump of shrubs growing about fifty feet to the west, where she suddenly vanished upon reaching that point. This behaviour instantly meant one of two possibilities—either she had stopped to visit flowers, or she had entered her nest close by. Keeping these particular shrubs under close scrutiny to detect a possible continued flight, I quickly made my way to them but, upon arrival, found neither flowers nor the queen. This prompted an immediate cursory examination of a circular area with approximately a twelve-foot radius from the clump of shrubs. When no trace of the queen was found by so doing, my attention was then directed to the shrubs themselves, which represented a species about six feet tall and similar in habitus to *Psidium*, but the leaves were definitely leathery-like and glabrous. When the clump was parted for close inspection I observed that the soil at its base was well covered with dried leaves and that there were two or three old stubs among the new growth, indicating that the vegetation had once been cut over. When the leaf duff at the base of the clump of shrubs was disturbed by foot pressure I heard the familiar buzzing sound of the queen not far beneath the surface to the side of one of the stubs. I carefully removed enough of the loose dried leaves to find the partly concealed nest entrance, which was slightly less than three-fourths of an inch in diameter and about only eight inches from where the queen seemed to be located. The site was well drained and had been sheltered from rain by dense foliage and completely shaded, at least during the hours of brightest sunlight.

Before causing further disturbance, I photographed the site from distances of about fifteen and seven feet, then proceeded to investigate the nest. The queen was captured after removing a layer of leaf litter and soil, combined not more than approximately two inches thick. When first exposed, she acted much excited, as do queens with nests in this stage, but made no attempt to desert the brood or to escape. The small cluster of brood and, at the side, a honey pot separated by a distance of less than one-half inch, were situated in a widened part of what appeared to be a small mammal burrow just beneath the soil surface. Later search revealed that this burrow did not lead to any larger subsurface cavity (which might have served as an identification clue), consequently, even the probable identity of the animal responsible for it remains unknown. The oval cavity surrounding the brood was about three inches long and two inches wide, lined

[1]The writer gratefully acknowledges the financial support given by the American Philosophical Society, Grant No. 1931, Penrose Fund, for South American bumblebee research, of which this report is a part.

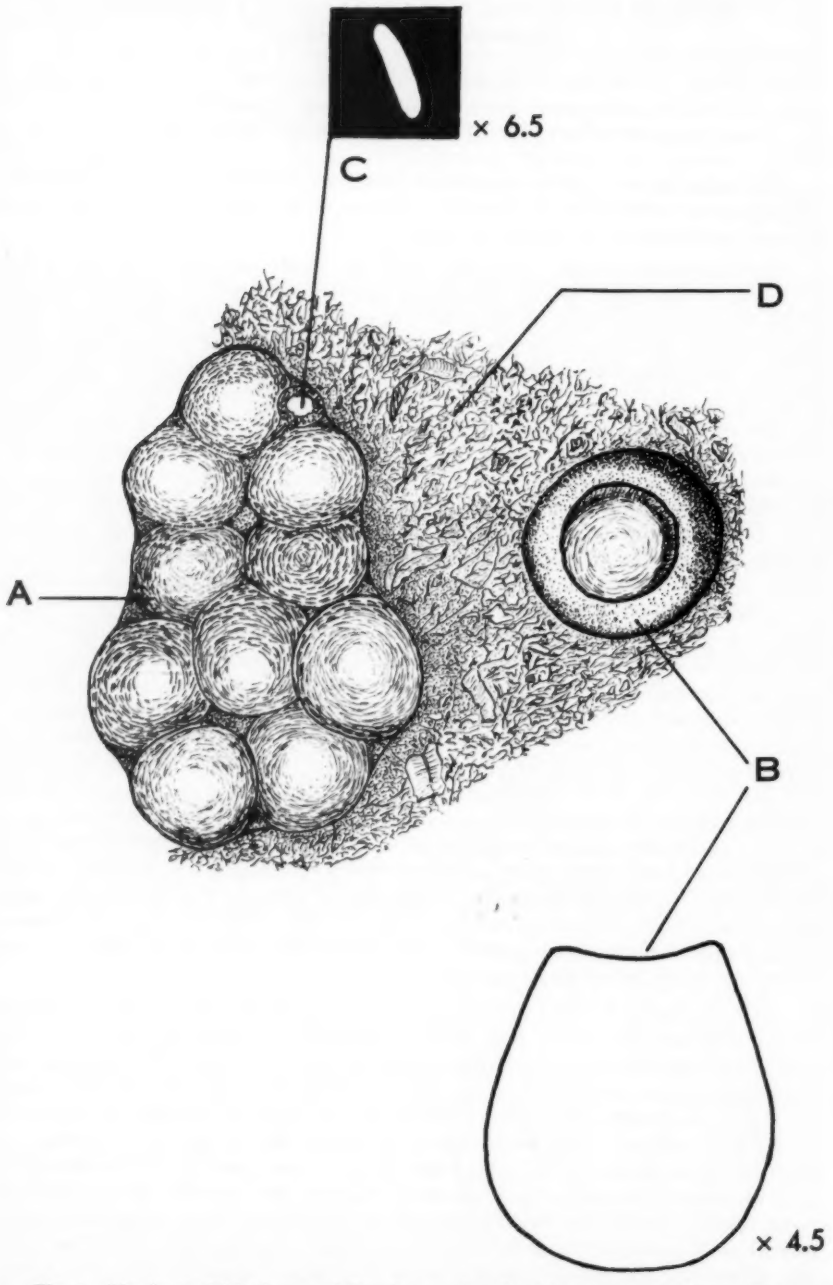


Fig. 1. Newly established nest of *Bombus morio* (Swed.): A—brood cluster; B—honey pot, showing lateral outline below; C—egg, taken from indicated cell; D—bottom of nest in part, illustrating assortment of plant particles employed as lining.

below and at the sides with small, irregular bits of dried leaves, roots and rootlets (shown in part, Figure, D) and the top consisted of a thin layer of humus supported by numerous fine rootlets. The original burrow continued for a short distance beyond that portion occupied by the queen and her brood. It is certain that if this nest had been allowed to develop it would have been necessary for the bees to have increased the size of the cavity progressively as the colony became larger.

The entire contents of this nest were carefully removed, placed in natural position on the most suitable available background (white insect net), photographed at a distance of three feet, then properly packed in a container for transfer to a place where it could be studied later. Field notes and sketch indicate that the brood comprised eleven cells, all completely closed except a small one containing eggs, and that it had a rather broad, transverse, conspicuous brood concavity near the middle. Late on the same day it was re-examined more closely and found to contain six full-grown larvae, which had already spun or began to spin, four smaller larvae from one-half to three-fourths grown in less rigid cells having walls with considerable wax, and six white, elongate-oval eggs. All eggs were contained in the one small, not completely closed cell made mostly of soft wax lined with some pollen at the bottom, and were placed side by side with the longitudinal axis of each more or less vertical. Each egg (Figure, C) measured 3.5 mm. in length and 1.0 mm. in diameter. These were preserved in fluid (KAAD). The brood cluster (Figure, A) measured 33.0 mm. in length, 22.0 mm. at the wider half, 17.0 mm. at the narrower half, and 16.0 mm. across near the middle (brood concavity). The honey pot (Figure, B) was constructed of wax, intermixed with soil and plant particles, measured 14.0 mm. in height, 13.0 mm. in greatest diameter, and had an 8.0 mm. circular opening; when taken, it was three-fourths filled with honey. There was no evidence of any freshly collected pollen deposited anywhere on the brood cluster in a pocket or pouch, which was not to be expected with a nest so recently established. At this time only two of the full-grown larvae were dissected from their cells and preserved in fluid, as it was my intention to keep the remaining specimens alive as long as possible.

No further attention was given the material until my arrival at São Paulo, November 7, when the specimens were again examined; they were still alive and apparently in good condition. Unfortunately, due to circumstances not conducive to rearing, very shortly thereafter it became advisable to dissect out and preserve the specimens, two of which had already pupated in their cells that had then become definitely more rigid than those of the larvae. The material from this nest, including some of the interior lining, is contained in the writer's research collection.

(Received May 3, 1961)

Some Notes on the Dipterous Enemies of Aphids Harmful for Apple Growing in Nova Scotia

By H. H. Evenhuis

Research Station, Canada Department of Agriculture, Kentville, Nova Scotia
and Institute of Phytopathological Research, Wageningen, Netherlands

During a stay at the Research Station, Canada Department of Agriculture at Kentville, Nova Scotia, from July 3 to October 16, 1959, I had the opportunity to make some observations on the natural enemies of the woolly apple aphid, *Eriosoma lanigerum* (Hausm.), the rosy apple aphid, *Dysaphis plantaginea* (Pass.), and the green apple aphid, *Aphis pomi* Deg. An inventory of these enemies was made in the Annapolis Valley in apple orchards, sprayed according to the principles of the spray schedule of Dr. A. D. Pickett. This schedule avoids spraying with fungicides and insecticides such as sulphur and phosphorus compounds, which are very harmful to the enemies of a number of pests, studied by Dr. Pickett and his staff (cf. Pickett 1959). The dipterous predators and their enemies are dealt with in this paper.

Observations

The Dipterous Enemies of the Woolly Apple Aphid

Neocnemodon elongata (Cn.) (Diptera, Syrphidae) was observed as a larva in woolly aphid colonies in several orchards; 14 specimens (nine males and five males) were reared to adults with woolly aphids. The flies emerged between July 30 and September 2. It should be noted that the investigations were started in late July; therefore it may be possible that adults were already present in the field before July 30.

From the puparia the following parasites emerged: *Phthorima bidens* Davis (Hymenoptera, Ichneumonidae) or a closely related species, eight specimens (one from each puparium) emerging between August 7 and 31, and *Lygocerus* sp. (Hymenoptera, Ceraphronidae), 14 specimens (one male and 13 females) emerging from one puparium on August 12.

In Europe a different but related species of syrphid fly, *Neocnemodon vitripennis* (Meig.), acts as a predator of the woolly apple aphid (Evenhuis 1959). It is reasonable to expect, that *Neocnemodon elongata*, like *N. vitripennis*, is restricted in its prey to aphids with dense, flocculent wax secretions, living in dense colonies on trees and shrubs.

Metasyrphus wiedemanni (John.) (Diptera, Syrphidae) was also often observed as a larva in colonies of the woolly apple aphid; 19 specimens (13 males and six females) developed into adults with woolly aphids as prey. The adults emerged between August 24 to October 6. A number of adult flies, however, stayed within the puparia; the temperature probably was too low for emergence in that period. From one of the puparia a parasite, *Syrphoctonus agilis* (Cress.) (Hymenoptera, Ichneumonidae), emerged on October 13.

One specimen of *Syrphus vittaʹrons* Shan. (Diptera Syrphidae) was reared from the larva with woolly aphids. It was collected at Port Williams; the adu't appeared on October 6.

Recapitulating, it may be said that in the summer of 1959 two important Syrphid predators of the woolly apple aphid were present in Nova Scotia, viz. *Neocnemodon elongata*, probably nearly monophagous and present in the field as an adult fly until about September, and *Metasyrphus wiedemanni*, polyphagous and present in the field from the end of August until autumn.

The Dipterous Enemies of the Rosy and the Green Apple Aphid

During the whole season many orange gall midge larvae (*Phaenobremia* sp., Diptera, Cecidomyiidae) were observed in colonies of the green apple aphid. Also a conspicuously coloured, brownish-red Syrphid fly larva (Diptera, Syrphidae) with the extreme fore-part bright red and with yellow light cross stripes on the rest of the body was often observed among green apple aphids. Perhaps it was *Metasyrphus vinelandi* (Cn.), which was bred once by me from a larva, collected from a colony of green apple aphids at Morristown. A parasite, *Aspicera* sp. (Hymenoptera, Cynipidae), which emerged from a puparium of this species, was also collected in a colony of the green apple aphid at Morristown.

Small dipterous larvae were observed in great quantities, especially at the end of July and the beginning of August, in colonies of the rosy apple aphid on the undersides of the curled leaves and particularly on the leaves and twigs infested with green apple aphids. Some were reared to the adult stage, mostly by keeping the leaves and twigs with aphids and dipterous larvae in plastic bags in the laboratory for some days. The full-grown larvae often crawl to the plastic to make their puparia. These puparia were collected in glass vials; the adults emerged about a week later. Two species, viz., *Leucopis americana* Malloch and *Leucopis* sp. (Chamaemyiidae) were bred from both aphids, the latter species probably is a new one.

According to Mr. McAlpine the puparia of both species may be easily distinguished; the puparium of *L. americana* being pale yellowish-brown in colour and bearing very numerous, short, fine papillae and that of *Leucopis* sp. being dark reddish brown with the papillae much sparser and coarser.

From one puparium a parasite, *Melanips* sp. (Hymenoptera, Cynipidae), emerged.

Both *Leucopis* species probably are important predators of both the rosy and the green apple aphids.

Acknowledgments

My journey to and my stay in Kentville were enabled by a stipend from the N.A.T.O., for which I want to express my thanks. Thanks are also due to Dr. A. D. Pickett and his staff for the hospitality and the help which I received at the laboratory at Kentville, and to several specialists, who identified the predators and parasites, mentioned in this paper: Dr. J. Vockeroth (Diptera, Syrphidae), Mr. G. S. Walley (Hymenoptera, Ichneumonidae), Dr. L. Smith (Hymenoptera, Cynipidae and Ceraphronidae), Mr. J. F. McAlpine (Diptera, Chamaemyiidae), all from the Entomology Research Institute at Ottawa and Mr. W. C. Nijveldt (Diptera, Cecidomyiidae) from the Institute of Phytopathological Research (I.P.O.), Wageningen, Netherlands.

References

Evenhuis, H. H. 1959. *Cnemodon vitripennis* (Meig.) as a predator of the woolly apple aphid. *Ent. Ber.* 19: 238-240. [Dutch, with English summary].

Pickett, A. D. 1959. Utilization of native parasites and predators. *J. Econ. Ent.* 52: 1103-1105.

(Received February 1, 1961)

A Note on Resistant Root Maggots, *Hylemya* spp., as Pests of Flue-cured Tobacco in Southwestern Ontario[1]

By J. A. Begg
Entomology Laboratory, Chatham, Ontario

The maggot complex of *Hylemya cilicrura* (Rond.) and *H. liturata* (Meig.) attacked flue-cured tobacco transplants in southwestern Ontario in increasing numbers from 1958 to 1960. Previously they had been of very minor importance to tobacco in this area.

Resistance was suspected near Delhi, in Norfolk County, when abnormal infestations developed in soil treated with aldrin or heptachlor. Planting-water treatments of aldrin, dieldrin, heptachlor, or lindane also failed to give appreciable control. Similar increases in house-fly populations, coincidental with decreased susceptibility to chlorinated hydrocarbon insecticides, have been noted (2).

In May, 1960, Diazinon wettable powder at 1.0 ounce of toxicant per 45 gallons of planting water generally eliminated injury by maggots to tobacco. The number of puparia was reduced from seven to less than one per whole-wheat flour bait used to measure abundance (4). A broadcast soil treatment of Diazinon at 1.5 pounds per acre reduced the injury from 65 to seven per cent, and the number of puparia from seven to three per bait. Maggot feeding injury and number of puparia were slightly higher in soil treated with aldrin at 3.0 pounds per acre than in untreated soil. Aldrin normally provides excellent control of *H. cilicrura* (3).

Most of the tobacco land in southwestern Ontario has been treated each year since 1954 with aldrin or heptachlor for control of cutworms and wireworms. According to Chapman (1), subjecting insects to regular insecticide applications favours development of resistance. Assuming there were four generations per year (4), from 1954 to 1957, resistance appeared in both species of this root maggot complex after about 16 generations of selection pressure. Control measures for cutworms and wireworms thus favoured the development of a new serious pest complex of tobacco and resulted in resistance to chlorinated hydrocarbon insecticides in these insects for the first time.

References

Chapman, R. K. 1960. Status of insecticide resistance in insects attacking vegetable crops. *Misc. Publ. Ent. Soc. Amer.* 2: 27-39.

Kilpatrick. J. W. and H. F. Schoof. 1956. Fly production in treated and untreated privies. *Publ. Hlth. Rep.* (*Wash.*) 71: 787-796.

Kuwayama, Satoru, Kiyoshi Sakurai and Kazue Endo. 1960. Soil insects in Hokkaido, Japan, with special reference to the effects of some chlorinated hydrocarbons. *Jour. Econ. Ent.* 53: 1015-1018.

Miller, L. A., and R. J. McClanahan. 1960. Life history of the seed-corn maggot, *Hylemya cilicrura* (Rond.) and of *H. liturata* (Mg.) (Diptera:Anthomyiidae) in southwestern Ontario. *Canad. Ent.* 92: 210-221.

(Received May 3, 1961)

[1]Contribution No. 9, Entomology Laboratory, Research Branch, Canada Department of Agriculture, Chatham, Ontario.

The Genera *Bak*, New Genus, and *Cheletomimus* Oudemans, with Descriptions of Three New Species (Acarina: Cheyletidae)

By CONRAD E. YUNKER[1]
Entomology Research Institute
Research Branch, Canada Department of Agriculture
Ottawa, Ontario

Through the kindness of Dr. E. W. Baker of the Entomology Research Division, U.S. Department of Agriculture, and Dr. J. F. G. Clarke of the U.S. National Museum, Smithsonian Institution, I was provided with a number of mites of the family Cheyletidae. Among these were specimens of two new species representing a new genus, and a new species of *Cheletomimus* Oudemans, formerly monotypic.

Bak, new genus

Cheyletidae; idiosoma elongate and narrow with a single, pentagonal propodosomal shield and three or four hysterosomal platelets; eyes absent; palpal genu small and cryptic; palpal claw of female with two basal teeth; palpal tarsus of female with two comblike and two sicklelike setae; coxae I and II contiguous, widely separated by an expanse of integument from coxae III and IV, the latter coalesced into common posterolateral plates; leg I with claws.

Type-species: *Bak sanctaehelenae*, new species.

Remarks: The new genus resembles *Chelacheles* Baker, 1958 (Type: *C. strabismus* Baker, 1958) in its elongate, narrow idiosoma and coalesced posterior coxae. It is no doubt closely related to this form, but following present concepts cannot be considered congeneric. *Chelacheles* has a well developed and obvious palpal genu, is without differentiated dorsal shields or platelets, has eyes, and is constricted medially. *Bak* differs diametrically in these attributes. It may be further separated from *Chelacheles* by the integumental striations, which are transverse rather than longitudinal for the greater part of the dorsum.

The name *Bak* is an arbitrary combination of letters treated as masculine. It is hoped that its brevity will add a note of respite to the list of twenty-odd generic names currently in use that are so confusingly similar (*Cheyletus, Cheyletia, Cheyletiella, Eucheyletia, Cheletogenes, Cheletophanes, Cheletophyes, Cheletonella*, etc.).

Differential diagnosis: Females of the two species of *Bak* may be distinguished by the following couplet.

Idiosoma more than three times longer than wide; genital opening with four pairs of associated setae; genu II and trochanters III and IV with a single seta each; associated with oak and pine ..... *sanctaehelenae*, new species

Idiosoma approximately two times longer than wide; genital opening with two pairs of associated setae; genu II and trochanters III and IV without setae; associated with *Casuarina* ..... *deleoni*, new species

Bak sanctaehelenae, new species

(Fig. 1)

HOLOTYPE, FEMALE. An elongate, narrow mite with short legs. Length, measured dorsally exclusive of gnathosoma, 535 μ; width, measured dorsally at midpoint, 175 μ.

Idiosoma: Dorsum with a single propodosomal shield and three hysterosomal platelets. Propodosomal shield pentagonal in shape, with rounded angles,

[1]Present address: Laboratory of Tropical Virology, Middle America Research Unit, National Institute of Allergy and Infectious Diseases, National Institutes of Health, Balboa Heights, Canal Zone.

overlaid with indefinite longitudinal integumental striations; dimensions: 140 μ long at midline, 83 μ wide at anterior angles, 110 μ wide at posterior angles. Propodosomal shield with three pairs of short marginal setae and a single pair of longer submarginal setae, all of which arise from bases set in large ovoid plaques on surface of shield; first (anterior) pair of marginal setae arising at anterior angles of shield; second pair arising at a point approximately one-third the distance from anterior marginal to posterior marginal setae; third (posterior) pair arising at posterolateral angles of shield; single pair of submarginal setae arising anteriorly at level of first marginals and approximately one-fifth the distance from lateral border to midline; all shield setae bluntly lanceolate and indefinitely pilose. Eyes absent. Remainder of dorsum densely striated; striations transverse throughout midlength of body except at bare areas at setal bases, shield, and platelets, at which points circumbscribing and conforming to these areas. Dorsal integumental setae consisting of five bluntly lanceolate, indistinctly pilose pairs, slightly longer than propodosomal shield setae; a single elongate, whiplike lateral pair; two weak, short subterminal pairs; and a single stronger, longer terminal pair arising from posterior tip of opisthosoma. All dorsal setae arising from bases set in unstriated areas of dorsum: the first pair set closely together submedially, halfway between posterior tip of propodosomal shield and transverse axis of body; the second and third pairs located in a single row across body at some distance posterior to midline; the fourth pair arising submedially at a level with insertions of coxae III, the bases each being set in the posterior-most portion of a somewhat larger area (referred to above as a platelet) than those of the first, second and third pairs; a similar bare area, or platelet, located between the fourth pair; the fifth pair arising submedially from bases set in a common median bare area, and at a level with anterior insertions of coxae IV.

Venter striated except for areas at setal bases; striations circumscribing and conforming to these areas. With three pairs of simple body setae and four pairs of genital setae. The first pair of body setae short, arising from bases set in unstriated areas between coxae II; second pair extremely elongate, whiplike, arising from bases set submedially in unstriated areas on transverse axis of idiosoma; third pair similar to first pair, located submedially and caudad of second pair; the four pairs of genital setae short, bordering a cuneiform genital opening.

Gnathosoma: Length, measured dorsally from posteromedian border to tip of rostrum, 120 μ; width, measured at anterolateral margins of fused coxae-trochanters, 108 μ. Gnathosomal base ring faintly striate, with pair of dorsal pores and a pair of elongate ventral setae. Rostrum conical, with a minute pair of apical setae and a longer pair of penultimate setae arising from knoblike eminences. Peritreme "W-shaped", composed of two pairs of members, an outer pair of seven segments and an inner pair of eight segments, the former meeting the latter in fractate apposition at spiracle located just posterior of bases of penultimate rostral setae. Femur slightly wider than long, outer margin very slightly convex; with three simple setae: one dorsal and two ventral. Genu small, cryptic, closely associated with tibia; with one dorsal and one ventral seta. Tibia wider than long; with one dorsal and two ventral setae, and a claw. Palpal claw elongate and narrow; with two basodorsal teeth on inner margin, the proximal tooth thick and broad, the distal one narrow and fingerlike. Tarsus small, arising from inner and dorsal aspect of tibia; with two dorsal comblike setae and two ventral sicklelike setae; outer comblike seta longest, with 28-32 tines; inner comblike seta two-thirds as long, with 28-32 tines; inner sicklelike seta slightly more than one-half the length of outer sicklelike seta.

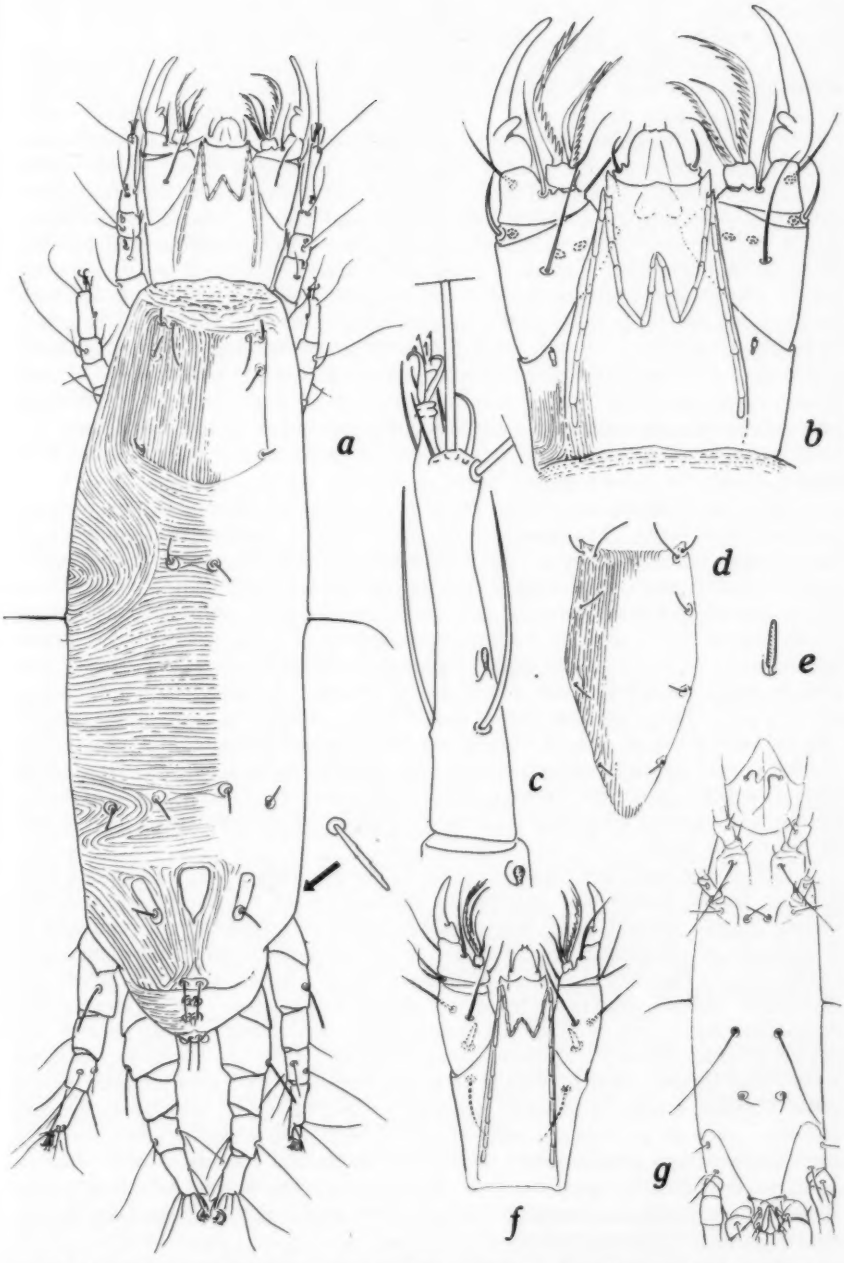


FIG. 1. *Bak sanctaebelenae*, n.sp.: *a*, female, dorsal view; *b*, gnathosoma, female, enlarged; *c*, tarsus I, female; *d*, propodosomal shield, male; *e*, sensory rod of tarsus I, male; *f*, gnathosoma, male; *g*, venter, female.

Legs: All segments except tarsi short and telescoped. Legs I and II directed anterolaterally; legs III and IV directed posteriorly, their coxae separated from those of anterior pairs by an extremely large part of integument.

(I) Coxa triangular, large; bearing a short simple apical seta and an elongate, whiplike median seta. Trochanter short, bearing a short, simple apical seta. Femur longer than broad, with a straight inner margin and a convex outer (dorsal) margin; with an elongate, simple dorsal seta and a shorter simple ventral seta. Genu narrower and shorter than femur; bearing a short, simple dorsal seta and a minute, club-shaped, dorsal sensory rod. Tibia narrower and shorter than genu; bearing an elongate, whiplike dorsal seta, a minute, club-shaped, dorsal sensory rod, and two simple ventral setae. Tarsus narrower than tibia, elongate, comprising 40% of total length of all free segments of leg; terminating abruptly in a large setiferous knob and a thin, claw-bearing stalk. Sensory seta a minute, blunt, striated rod, arising dorsally one-third of the distance from base of tarsus to tip of claws, and immediately distad of an elongate, simple, dorsal guard seta. Ventral surface of tarsus with a seta similar to dorsal guard seta. Dorsal setiferous knob bearing two elongate simple setae, and one short thick seta. Claw-bearing stalk with two short, thick dorsal setae and two short, fine ventral setae. Posttarsus consisting of paired claws and a padlike empodium with a double row of 4-6 tenent hairs.

(II) Coxa triangular, smaller than and contiguous with coxa I; with an elongate simple seta. Trochanter short; with a simple apical seta. Femur longer than broad; with an elongate, simple dorsal seta and a shorter, simple ventral seta. Genu shorter and narrower than femur; with a short, simple ventral seta. Tibia shorter and narrower than genu; with an elongate, whiplike dorsal seta, a short, simple dorsal seta, an elongate, simple ventral seta, and a shorter simple ventral seta. Tarsus shorter and broader than tarsus I; setiferous anterodorsal protuberance present but not as eminent as in tarsus I; narrowing to an apical, claw-bearing stalk. Setae of tarsus II as follows: one short, thick, blunt sensory rod on basal third of ventral surface just proximad of a longer, simple seta; one elongate, thin, simple seta, one intermediate-size similar seta and one short thick seta on anterodorsal protuberance; three short setae on stalklike apex of tarsus. Posttarsus consisting of paired claws and a padlike empodium with a double row of 4-6 tenent hairs.

(III) Coxa fused with that of leg IV to form a single plate. This plate with a short, simple lateral seta anterior to articulation of trochanter III, and two longer, simple ventral setae, one at articulation of trochanter III and one at articulation of trochanter IV. Trochanter with a short, simple ventrolateral seta. Femur longer than broad; with a moderately long, bluntly lanceolate, pilose seta on dorsal surface, similar to those on dorsal integument. Genu shorter and narrower than femur; with an elongate simple ventral seta. Tibia shorter and narrower than femur; with four setae: dorsally with one elongate, whiplike simple seta and one shorter, simple seta, and ventrally with two elongate simple setae. Tarsus similar in size and structure to that of leg II; with seven setae as follows: one simple seta on mid-ventral surface; two elongate and two short setae on setiferous protuberance of dorsal surface; and two short, fine setae on ventral side of stalklike apex of tarsus. Posttarsus slightly larger and stronger than those of legs I and II; consisting of two claws and a padlike empodium having two rows of 8-12 tenent hairs.

(IV) Trochanter with a small, simple ventral seta. Femur heavy, longer than broad, with a straight ventral margin and a convex dorsal margin; bearing a moderately long, bluntly lanceolate, pilose seta similar to those of dorsal

surface. Genu rectangular, slightly longer than broad, shorter than femur; without setae. Tibia, tarsus and posttarsus similar to those of legs III.

MALE. An elongate mite, similar to female but shorter, and with a longer, narrower gnathosoma. Length, measured dorsally exclusive of gnathosoma, 424 μ; width, measured dorsally at midpoint 162 μ.

Idiosoma: Dorsum with a single propodosomal shield and three hysterosomal platelets. Propodosomal shield in the shape of an elongate pentagon, overlaid with vague, longitudinal integumental striations; dimensions: 230 μ long at midline, 75 μ wide at anterior margin. All dorsal setae similar in shape and arrangement to those of female with the following exceptions: dorsal shield extended to include a fifth pair of setae (the first dorsal integumental setae of the female); three pairs of subterminal setae (excluding elongate terminal setae) arising from a single platelet, the first pair of these short and thick (as opposed to elongate homologous setae of females). Eyes absent. Dorsum striated as in female. Median platelet of hysterosomal group connected to subterminal platelet by a constricted isthmus.

Venter striated as in female; with four pairs of simple body setae arranged as in female, and a fifth pair located subterminally on opisthosoma.

Gnathosoma: Elongate and narrow; length, measured dorsally from posteromedian border to tip of rostrum, 175 μ; width, measured at anterolateral margins of fused coxae-trochanters, 150 μ. Gnathosomal base ring striate, with a pair of dorsal pores and a pair of simple ventral setae. Rostrum conical, with a pair of small apical setae and a pair of longer penultimate setae arising from knoblike eminences. Peritreme as in female, but with nine outer segments and seven inner segments. Femur longer than wide, with a convex outer margin and a concave inner margin; bearing an elongate, simple dorsal seta, a similar ventral seta and a ventral spur or calcar[2]. Genu and tibia as in female. Palpal claw elongate and narrow, with a single basal tooth. Tarsus small, arising from dorsal and inner aspect of tibia; bearing a single comblike seta with 30-36 tines, three simple sicklelike setae of varying size, and a small blunt sensory rod.

Legs: Similar to those of female, with following exceptions: dorsal sensory rod of tarsus I and tarsus II slightly longer and stouter than those of female; tibia II with a blunt, dorsal sensory rod and four simple setae: one elongate and dorsal, one shorter and dorsal, and two shorter and ventral; tibia III with a blunt, dorsal sensory rod and four simple setae: one elongate and dorsal, one shorter and dorsal, and two shorter and ventral; tibia IV with a blunt dorsal sensory rod, an elongate, simple dorsal seta, a short, simple dorsal seta, and two short ventral setae; tarsus III and IV each with a blunt, ventral sensory rod in addition to seven simple setae possessed in common with those of female.

NYMPH. Similar to female; elongate and narrow; with short legs that are evenly tapered rather than telescoped from proximal to distal aspect. Length, measured dorsally exclusive of gnathosoma, 368-524 μ (average, 449 μ); width, measured dorsally at midpoint 110-178 μ (average, 157 μ).

Idiosoma: Dorsum and venter similar to those of females, but with two rather than four pairs of genital setae; without genital opening.

Gnathosoma: Similar to that of female. Length, measured dorsally from posteromedian border to tip of rostrum, 89-108 μ (average, 100 μ); width, measured at anterolateral margins of fused coxae-trochanters, 80-110 μ (average, 100 μ).

[2]See Crabill (1960, Proc. U.S. Nat. Mus. *III* [3422]: p. 13, 14) for an enlightened discussion of spurs, spines and setae.

Legs: All segments except tarsi I short; legs broadest proximally and tapering distally, especially III and IV. Setation similar to that of female.

Type material: Holotype female [U.S.N.M. No. 2683] from "dense woods of oak and pine", California, Napa Co., Mt. St. Helena, 14 August, 1952, S. F. Bailey, coll. Paratypes: one female, six nymphs, bearing same data as holotype. Holotype female and three paratype nymphs deposited in the U.S. National Museum. Paratype female and two paratype nymphs deposited in the Canadian National Collection.

Other material: One male bearing the same data as the holotype is not included in the type series. Although the observed differences are here treated as sexual dimorphism, the male was not reared and the possibility exists that it is of a separate species.

Bak deleoni, new species

(Fig. 2)

HOLOTYPE, FEMALE. An elongate, narrow mite with relatively massive gnathosoma and short, telescoped legs. Length, measured dorsally exclusive of gnathosoma, 270 μ; width, measured dorsally at midpoint, 130 μ.

Idiosoma: Dorsum with a single propodosomal shield and four hysterosomal platelets. Propodosomal shield pentagonal in shape, with rounded angles, and overlaid with indefinite longitudinal integumental striations; dimensions: 105 μ long at midline, 71 μ wide at anterior angles, 95 μ wide at posterior angles. Propodosomal shield with three pairs of short marginal setae and a single pair of slightly longer submarginal setae; first (anterior) pair of marginal setae arising at lateral borders and slightly caudad of anterior border of shield; second pair arising at a point approximately one-third the distance from anterior marginal to posterior marginal setae and slightly mediad of lateral borders of shield; third (posterior) pair arising at posterolateral angles of shield; single pair of submarginal setae arising anteriorly at level of first marginals and approximately one-fifth the distance from lateral border to midline; all shield setae bluntly lanceolate and pilose. Eyes absent. Remainder of dorsum densely striated; striations transverse at transverse axis of body, but circumscribing and conforming to bare areas at setal bases, shield and platelets at all other points. Dorsal integumental setae consisting of five bluntly lanceolate, pilose pairs slightly longer than propodosomal shield setae, two weak, short subterminal pairs, and a single stronger, longer terminal pair arising from pointed posterior tip of opisthosoma. Each seta of the five pilose pairs arising from a base set in an unstriated area of dorsum; the first pair arising at a point just laterad of posteromedian angle of propodosomal shield; the second and third pairs located in a single row across body and just posterior of transverse axis of body; the fourth pair arising submedially at a level with anterior insertions of trochanters III, their bases each being set in a somewhat larger unstriated area (referred to above as a platelet) than those of the first, second and third pairs; a similar bare area, or platelet, located between the fourth pair; the fifth pair of pilose setae arising submedially from bases set in a common median bare area, or platelet, and at a level with anterior insertions of trochanters IV.

Venter striated except for areas at setal bases; striations circumscribing and conforming to these areas. With four pairs of simple body setae and two pairs of simple genital setae. The first pair of body setae short, arising from bases set in unstriated areas between coxae II; the second pair elongate, whiplike, and arising from unstriated areas located ventrolaterally on transverse axis of body; the third pair similar to second pair but located submedially and just caudad of

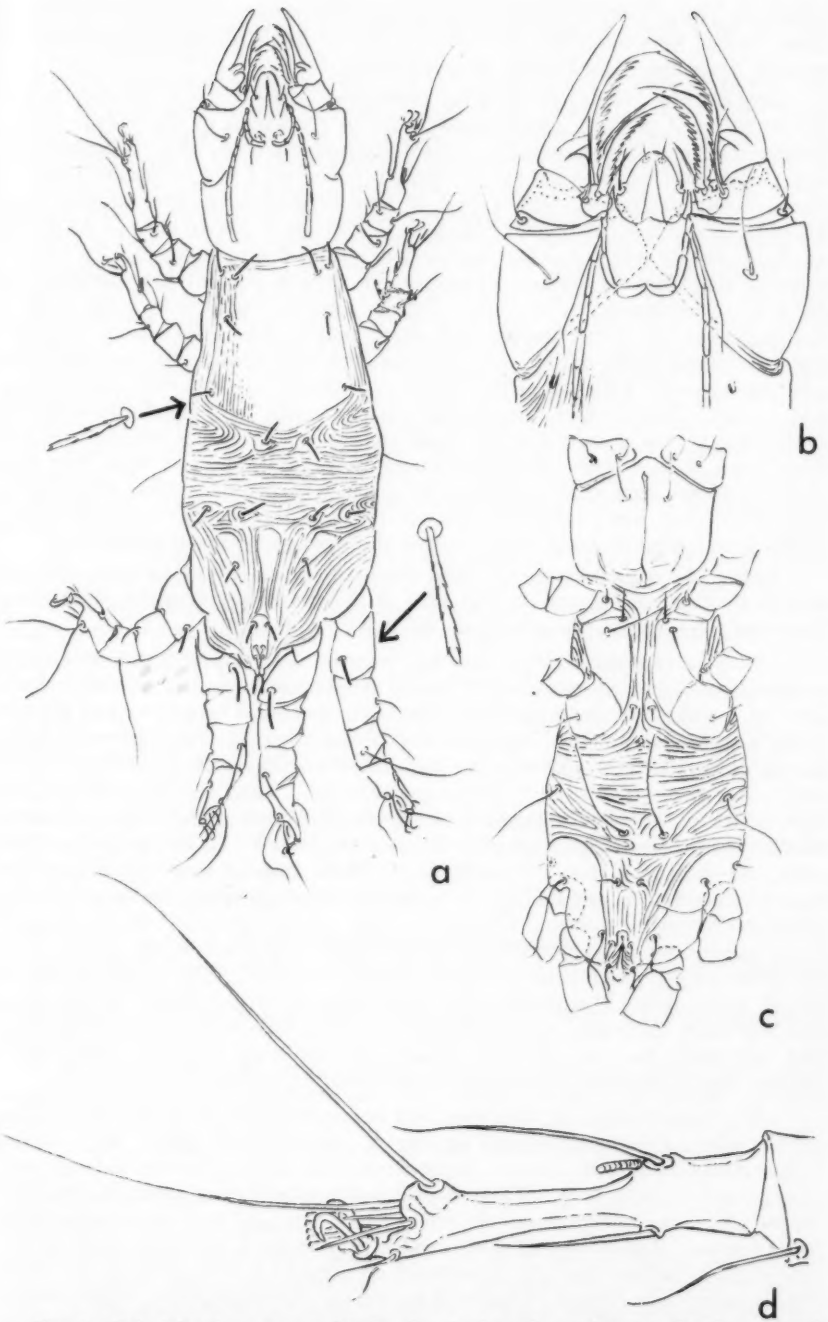


FIG. 2. *Bak deleoni*, n. sp.: *a*, female, dorsal view; *b*, gnathosoma, female, enlarged; *c*, venter, female; *d*, tarsus I, female.

transverse axis of body; the fourth pair similar to first pair, arising from unstriated areas located between coxae III. Two pairs of small, simple genital setae on striated integumental flap lining genital opening.

Gnathosoma: Massive; length, measured dorsally from posteromedian border to tip of rostrum, 120 μ (nearly one-half the length of the body); width, measured at anterolateral margins of fused coxae-trochanters, 94 μ. Gnathosomal base ring faintly striate, with a dorsal pair of pores and a ventral pair of elongate setae. Rostrum conical, with a pair of longer penultimate setae arising from knoblike eminences. Peritreme "M-shaped", composed of two pairs of members, an outer pair of seven segments and an inner pair of four segments, the former meeting the latter in fractate apposition at spiracle located just posterior of bases of penultimate rostral setae. Femur slightly wider than long, with a shallowly convex lateral margin and three simple setae: one dorsal and two ventral. Genu small, cryptic, closely associated with tibia; with one dorsal and one ventral seta. Tibia wider than long; with one dorsal, and two ventral setae, and a claw. Palpal claw elongate and narrow; with two basodorsal teeth on inner margin, the proximal tooth thick and broad, the distal one narrow and fingerlike. Tarsus small, arising from inner and dorsal aspect of tibia; with two dorsal comblike setae and two ventral sicklelike setae, outer comblike seta longest, with 19-20 tines; inner comblike seta two-thirds as long, with 19-20 tines; inner sicklelike seta slightly more than one-half the length of outer sicklelike seta.

Legs: All segments except tarsi short and distinctly telescoped. Legs I and II directed anterolaterally; legs III and IV directed posteriorly, their coxae separated from those of anterior pairs by a decided gap.

(I) Coxa triangular, large, covering most of ventral propodosoma; bearing an elongate, simple ventral seta and a short, simple apical seta. Trochanter short; bearing a short, simple apical seta. Femur longer than broad, with a straight inner margin and a highly convex outer (dorsal) margin; bearing an elongate, simple dorsoapical seta. Genu narrower and shorter than femur; bearing a short simple dorsal seta and a short, dorsal sensory rod. Tibia narrower and shorter than genu; bearing one elongate and one short, simple dorsal seta, two short, simple ventral setae and a minute, dorsal sensory rod. Tarsus narrower than tibia, but measured from joint to tip of claws, as long as all preceding free segments combined; terminating abruptly in a large, setiferous knob and a thin, claw-bearing stalk. Sensory seta short, blunt, arising one-third of the distance from base of tarsus to point of origin of claws and immediately distad of an elongate, simple guard seta. Ventral surface of tarsus with a seta similar to dorsal guard seta. Dorsal setiferous knob bearing two elongate, simple setae and one short, thick seta. Claw-bearing stalk with two short, thick, dorsal setae and two short, fine ventral setae. Posttarsus consisting of paired claws and a padlike empodium with a (double?) row of 4-6 tenent hairs.

(II) Coxa rounded, smaller than and contiguous with coxa I; with a short, simple seta. Trochanter short; bearing a short, simple apical seta. Femur longer than broad; with a short, simple dorsal seta. Genu shorter and narrower than femur; without setae. Tibia shorter and narrower than genu; bearing four simple setae: one elongate and one short dorsal seta, and two intermediate-sized ventral setae. Tarsus shorter and broader than tarsus I; setiferous anterodorsal protuberance present but not as eminent as in tarsus I; narrowing to an apical, claw-bearing stalk. Setae of tarsus II as follows: one short, thick, blunt sensory rod on basal third of ventral surface just proximad of a longer, simple seta; one elongate thin, simple seta, one smaller, thick, pilose seta, and one short, thick

seta on anterodorsal protuberance; three short setae on stalklike apex of tarsus. Posttarsus consisting of paired claws and a padlike empodium with a double row of 4-6 tenent hairs.

(III) Coxa fused with that of leg IV to form a single plate extending the length of hysterosoma and reflected laterally and dorsally. This fused plate with a single, short dorsal seta in region of trochanter III, and two elongate ventral setae, one at level of insertion of trochanter III and the other at level of insertion of trochanter IV. Trochanter broader than long; without setae. Femur heavy, rectangular in outline; with a medium-sized, thick, bluntly lanceolate, pilose seta on dorsal surface similar to those on dorsal integument. Genu shorter and narrower than femur; with a short, thin, simple apicoventral seta. Tibia shorter and narrower than genu; with four setae: dorsally with one elongate simple seta and one short simple seta, and ventrally with two elongate simple setae. Tarsus shorter and broader than tarsus II; with an anterodorsal setiferous protuberance and an apical claw-bearing stalk. Tarsal setae as follows: one moderately long, slightly serrate seta on mid-ventral surface; two elongate and two short setae on setiferous protuberance of dorsal surface, the shorter pair distinctly pilose at distal end; and two short, fine setae on ventral side of stalklike apex of tarsus. Posttarsus larger in size than those of legs I and II; consisting of two claws and a padlike empodium having two rows of 9-11 tenent hairs.

(IV) Trochanter rectangular in outline, slightly longer than broad; without setae. Femur heavy, longer than broad, with a straight ventral margin; bearing a moderately long, bluntly lanceolate, pilose seta similar to those on dorsal integument. Genu slightly broader than long, shorter than femur; without setae. Tibia longer than broad, narrower than genu; with four setae: dorsally with one elongate simple seta and one short simple seta; and ventrally with two elongate, slightly serrate setae. Tarsus and posttarsus similar to those of leg III.

Type material: Holotype female [U.S.N.M. No. 2684], on *Casuarina*, Florida, Coral Gables, 29 June 1955, D. DeLeon coll. one paratype female, bearing same data.

Other material: A single, badly shrunken larva, on *Casuarina*, Florida, Coral Gables, 30 July 1955, D. DeLeon coll. All specimens deposited in the collection of the U.S. National Museum, Washington, D.C.

This species is named for its collector, Dr. D. DeLeon, acarologist.

Genus *Cheletomimus* Oudemans

Cheletomimus Oudemans, Entom. Ber. Nederl. Ver. *1*, fasc. 18, p. 163, 1904; *ibidem 5*, fasc. 120, p. 359, 1921.

Type-species: *Cheletomimus trux* Oudemans = *Cheletes berlesei* Oudemans (monotypic).

Cheyletidae; idiosoma rounded, with a short gnathosoma; female with three dorsal shields, one propodosomal and two hysterosomal; eyes present on propodosomal shield; palpal tarsus with two comblike and two sicklelike setae; legs I with claws. With two species: *C. berlesei* Oudemans and *C. denmarki*, new species.

Differential diagnosis: Females of the two species of Cheletomimus may be distinguished by the following couplet:

Propodosomal shield with seven pairs of setae; hysterosomal shields each with a single seta; palpal claw with seven teeth; dorsal seta of palpal tibia lanceolate and serrate; tarsus I with a simple dorsal guard seta *berlesei* (Oudemans).

Propodosomal shield with 13 pairs of setae; hysterosomal shields each with seven setae; palpal claw with thirteen teeth; dorsal seta of palpal tibia broad, leaflike and venose; tarsus I with an elongate, broad, leaflike, venose guard seta ..... *denmarki*, new species.

Cheletomimus berlesei (Oudemans)

Cheyletus ornatus Canestrini and Fanzago, Berlese, Acari, Myriapoda et Scorpiones hucusque in Italia reperta, Prostigmata, Fasc. 28 (6), 1886 (misidentification).

Cheletes berlesei Oudemans, Entom. Ber. Nederl. Ver. *1*, fasc. 17, p. 154, 1904.

Cheletomimus trux Oudemans, ibidem, fasc. 18, p. 163, 1904.

Cheletomimus ornatus (Berlese), Oudemans, Mem. Soc. Zool. France, *19*, pp. 136-139, figs. 34, 35, 1906. Vitzthum, Die Tierwelt Mitteleuropas *3* (3), p. 55, 1929. Baker, Bull. California Dept. Agric. *28* (4), p. 273, 1939.

Cheletomimus berlesei, Baker, Proc. U.S. Nat. Mus. *99* (3238), pp. 293-294, figs. 72-75, 1949. Volgin, Mites of the Rodent Fauna of the U.S.S.R. Izd. Acad. Sci. U.S.S.R., Moskva-Leningrad *59*, p. 172, figs. 245-247, 1955. McGregor, Mem. S. California Acad. Sci. *3* (3), p. 24, figs. 10-13 (Pl. 7), 1956. Dubinin, Parazitol. Sbornik *17*, p. 84, figs. A, B (Pl. 11), 1957.

Localities: Italy; Palestine; U.S.A.: California, Georgia[3], Florida[3], Mississippi[3]; Cuba (at Miami)[3]; Mexico[3].

Habitats: "Plants"; citrus, oranges; lemons; chinaberry[3]; leaf mold; willow[3]; *Epidendrum* sp.[3]; rose[3]; "'under *Aspidiotus lataniae*'"[3]; "in citrus red mite colony"; associated with *Tetranychus lewisi*".

Cheletomimus denmarki, new species

(Fig. 3)

Holotype, Female. A rounded mite with angular gnathosoma and short legs. Length, measured dorsally exclusive of gnathosoma, 204 μ; width, measured dorsally at midpoint, 175 μ.

Idiosoma: Dorsum with a single propodosomal shield and paired hysterosomal shields. Propodosomal shield semicircular in outline, rounded anteriorly and straight posteriorly; surface tuberculate; with thirteen pairs of large, squamiform, serrate setae and a single pair of lenslike eyes (holotype with a single unpaired seta on one side of shield in addition to thirteen pairs. Setae in the shape of a *Pecten* shell, with 8-12 ribs, each rib serrate on convex aspect. Eyes situated on anterolateral margins of shield between second and third pairs of setae. Hysterosomal shields semi-trapezoidal, with shortest dimension medial, widening to long lateral margin; shields small, each about one-third the area of propodosomal shield; each with tuberculate surface and seven setae similar to those on propodosomal plate. Remainder of dorsal integument between shields densely striate, with two pairs of lateral setae situated in region between legs II and III, and six pairs of setae situated on posterior of idiosoma. All dorsal integumental setae similar in form to those on dorsal shield.

Venter striated except for areas at setal bases; with five or six pairs of ventral body setae and five pairs of setae associated with genital opening. First pair of body setae arising from bases set in bare areas between coxae I; second pair more elongate than first, arising from similar areas located at a level just posterior of coxae II; third pair similar to second, located at a level between posterior insertions of coxae II; fourth pair one-half the size of third pair, arising at a level slightly anterior of genital opening; fifth pair similar to fourth pair, arising on either side of genital opening (holotype with a single unpaired seta, similar to those of fifth pair). Genital opening a longitudinal slit; bordered laterally by two striated integumental flaps, each flap having two pairs of short

[3]New records.

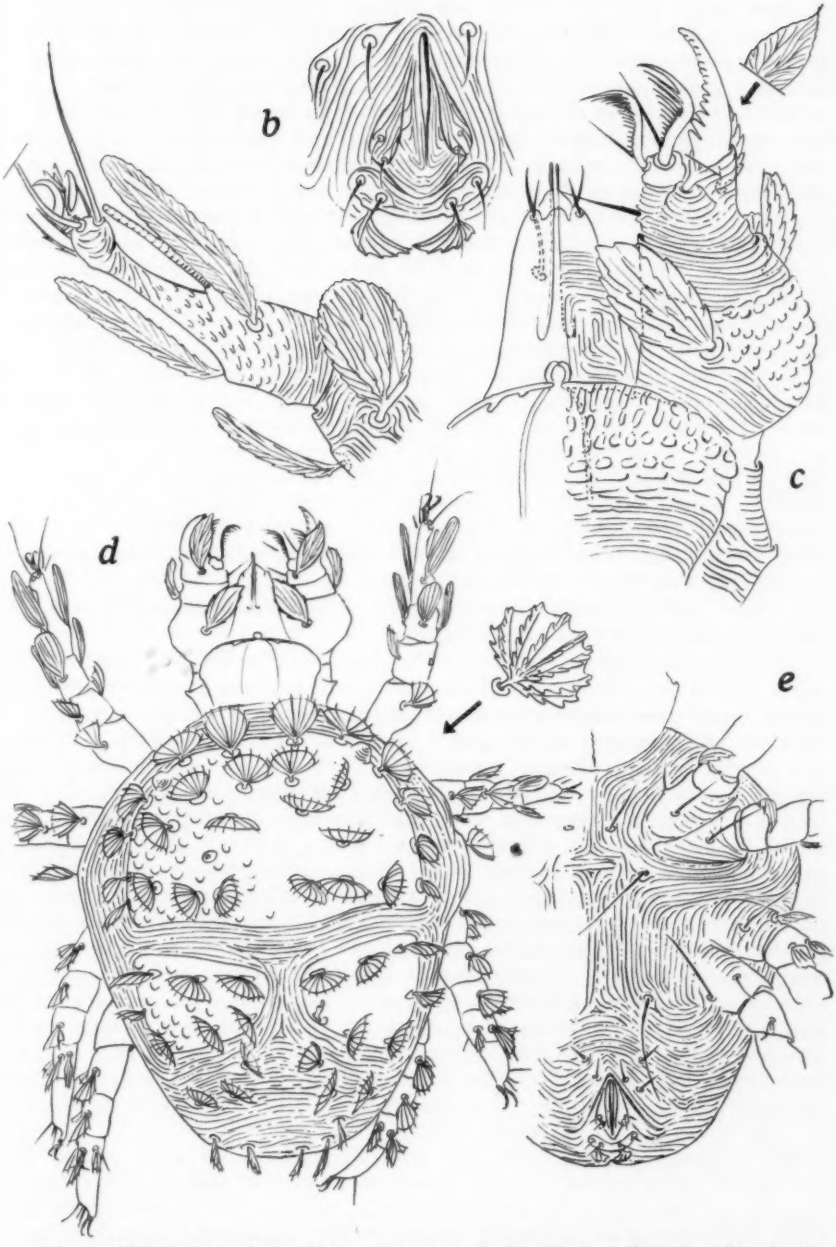


FIG. 3. *Cheletomimus denmarki*, n. sp.: *a*, tarsus I, female; *b*, genitoanal region, female; *c*, gnathosoma, female, enlarged; *d*, female, dorsal view; *e*, venter, female.

posterior setae; bordered posteriorly by a single, crescentic flap having two pairs of short simple setae and a single pair of short squamiform setae.

Gnathosoma: Relatively short, broad and angular. Length, measured dorsally from posteromedian border to tip of rostrum, 68 μ; width, measured at anterolateral margins of coxae-trochanters, 70μ; gnathosomal base ring "figure-8 shaped" rather than circular in cross sectional aspect (*i.e.*, having bilateral, longitudinal incisions that partially divide dorsal half of ring from ventral half). Ventral half of ring longitudinally striated, striations becoming transverse laterally and posterodorsally; with a pair of thick, elongate, simple setae. Dorsal half of ring with transverse posterior striations that become large, rounded tubercules medially and elongate tubercules anteriorly. Rostrum conical, striate dorsally; with a pair of short, simple, sub-apical setae arising from dorsal knoblike eminences, and a pair of elongate simple setae arising ventrally. Femur wider than long, angulate laterally, striate ventrally and basodorsally, tuberculate apicodorsally and laterally; with three setae: a mediodorsal one and two smaller medioventral ones, all of these similar in form to dorsal idiosomal setae, but more long than wide. Genu with one dorsolateral and one dorsoventral seta, each similar to the respective femoral setae. Tibia wider than long; with one dorsal and one ventral leaflike seta, each of which bear venations rather than ribs, a simple lateral seta, and a claw. Palpal claw curved, bearing 14 or 15 teeth along entire inner margin that decrease in size distally. Tarsus small, arising from inner and dorsal aspect of tibia; with two dorsal comblike setae and two ventral sicklelike setae. Outer comb largest with 14 or 15 tines; inner comb slightly smaller, with 14 or 15 tines. Inner sicklelike seta slightly shorter than outer sicklelike seta.

Legs: All segments short and striated. Legs radially arranged; coxae III and IV separate from those of legs I and II.

(I) Coxa rectangular; bearing an elongate, simple medial seta, and a shorter similar one on anterior margin. Trochanter short; with a squamiform apical seta. Femur longer than broad, with a straight inner margin and a deeply convex outer (dorsal) margin; bearing a large squamiform dorsal seta similar to those of dorsum, and a smaller, more elongate, squamiform ventral seta. Genu narrower and slightly shorter than femur; bearing a squamiform seta on inner margin. Tibia narrow and slightly shorter than genu; with five setae: a dorsal squamiform seta, a small dorsal sensory rod, a lateral squamiform seta on either side of the segment, and an elongate, simple, ventral seta. Tarsus slightly longer than combined length of genu and tibia, broad at base, tapering to a narrow stricture that gives rise to a setiferous protuberance and a short claw-bearing stalk; striated ventrally and basodorsally and tuberculate on distal two-thirds of dorsal aspect; bearing nine setae; one elongate squamiform seta arising dorsally and one arising ventrolaterally on basal third of segment, one heavy, blunt sensory seta arising from an elevated base located midway on dorsal surface of segment, two elongate simple setae and two short simple setae arising from terminal knoblike swelling, and two short ventral setae arising from base of claw-bearing stalk. Post-tarsus consisting of a pair of claws and a padlike empodium with a double row of 8-10 tenent hairs.

(II) Coxa triangular, anterior margin contiguous with coxa I, posterior margin merging insensibly with body wall; with a single, elongate, median seta. Trochanter similar to that of leg I. Femur rectangular in outline; with a squamiform dorsal seta similar to those on dorsum, and a leaflike posterolateral seta. Genu similar to femur but slightly smaller; with a squamiform dorsal seta and a leaflike anterolateral seta. Tibia slightly narrower and shorter than genu; with four setae: two squamiform, oval dorsal setae, a squamiform, elongate, ventral seta, and an elongate, simple ventral seta. Tarsus short as tibia, bluntly rounded; with

seven setae: a pair of elongate, simple apicodorsal setae, a pair of heavier, shorter, simple apicodorsal setae, a pair of serrate, apicoventral setae, and a single, simple ventral seta on midventer of coxa. Posttarsus similar to that of leg I.

(III) Coxa rounded medially, separated from coxa II by a gap equal to size of coxa; posterior margin merging insensibly with body wall; with two setae: an elongate simple medial seta, and a squamiform apical seta. Trochanter more elongate than those of legs I and II; with one apicodorsal and one apicolateral squamiform seta. Femur approximately equal in size to trochanter; with one squamiform dorsal seta similar to those of dorsum, and one leaflike ventral seta. Genu similar to femur. Tibia and tarsus similar to those of leg II. Posttarsus with slightly heavier claws than that of leg II; empodium with a double row of 12-14 tenent hairs.

(IV) Coxa rounded medially, contiguous with coxa III; posteriorly merging insensibly with body wall; with two simple setae: an elongate posterior one and a shorter anterior seta. Trochanter similar to that of leg III, but with only a single, small, squamiform, ventral seta. Femur similar to that of leg III, but with only a single, squamiform dorsal seta, resembling those of dorsum. Genu, tibia, tarsus and posttarsus similar to those of leg III.

NYMPH. Similar to female with following exceptions. Length, measured dorsoally exclusive of gnathosoma, 179-200 μ (average, 189μ); width at midpoint 169-175 μ (average, 171 μ).

Idiosoma: Propodosomal shield with eight pairs of setae; hysterosoma with two shields, each bearing three pairs of setae; a pair of smaller platelets between hysterosomal shields, each bearing a single seta; dorsal integument with five pairs of setae, one lateral and four posterior. Venter with six pairs of simple setae, two pairs of simple anal setae, and a single pair of squamiform postanal setae; without genital opening.

Gnathosoma: Length, measured dorsally from posteromedian border to tip of rostrum, 58-61 μ (average, 60 μ); width, measured at anterolateral margins of coxae-trochanters, 70 μ.

Legs: Trochanter IV without setae; femur IV with a single seta only. Type material: Holotype female [U.S.N.M. No. 2685], on *Litchi chinensis*, South tree, Florida, Clearwater, 7 December, 1959, L. B. Hill and E. W. Miller coll.; deposited in U.S. National Museum. Paratypes: two females, two nymphs bearing same data as holotype; two females, one nymph on *Aesculus pavia*, Florida, Gainesville, 7 August, 1959, G. W. Deckle and A. Peterson coll.; one female on *Ligustrum* sp., Florida, Largo, 17 April, 1959, Bingaman coll. Paratypes deposited in U.S. National Museum, Canadian National Collection and Collection of State Plant Board of Florida. Other material: one female on live oak leaf, Florida, Avalon, 12 March, 1948, O. D. Link coll.; one female on *Hibiscus* cuttings, Bermuda (at New York). W. B. McLellan coll.; one nymph on *Citrus sinensis*, Florida, Winter Haven, 19 August, 1949, L. C. Knorr coll.

Remarks: Variation in dimensions of all female specimens studied: length of idiosoma, 180-217 μ (average, 197 μ); width of idiosoma, 159-197 μ (average, 175 μ); length of gnathosoma, 67-75 μ (average, 71 μ); width of gnathosoma, 68-78 μ (average, 72 μ).

This species is named in honor of H. A. Denmark, Chief Entomologist, State Plant Board of Florida, who has done much to further the knowledge of Florida's acarine fauna.

(Received June 18, 1960)

The Effectiveness of Residues of Insecticides in Preventing Reinfestation of Apple Leaves by Apple Aphid, *Aphis pomi* DeG. II Thiodan and Guthion[1]

By D. P. Pielou and K. Williams[2]
Research Station, Research Branch, Canada Department of Agriculture
Summerland, British Columbia

Introduction

In a previous paper (16) an account was given of the relative efficiency of dry deposits of Diazinon [*0,0*-diethyl *0*-(2 isopropyl-4-methyl-6-pyrimidyl) phosphorodithioate], Trithion [*0,0*-diethyl *S*-(*p*-chlorophenylthiomethyl) phosphorodithioate] and Sevin[1-naphthyl *N*-methylcarbamate] in preventing the reinfestation of apple trees by the apple aphid, *Aphis pomi* DeG. In those experiments no comparison was made of the initial effectiveness of the insecticides in killing aphids by direct contact while the spray deposits were still liquid. Instead, interest was concentrated on the relative progress of recolonization of *aphid-free* trees, by aphids, as a measure of the effectiveness of dried and aging deposits. In the work reported here the results of similar investigations on two further aphicides are described.

Methods

The experimental conditions, and methods, were essentially the same as those of the former study (16). However, some changes were made in the second of the two methods for the assessment of the size of the aphid populations. The first method remained the same. It involved direct field observations, at intervals, on the size of the aphid colonies on specified leaves of tagged twigs from which the growing tips had been removed; the reason for this removal was that, otherwise, on the rapidly growing small terminal leaves, the insecticide deposit would be "diluted" simply by rapid increase in leaf area. Furthermore, it is not technically feasible to make residue deposit analyses from these small leaves. However, if a practical assessment of a particular aphicide is required it would be misleading to remove the growing tips as they are the most favoured sites for aphid development. In the previous study (16) this objection was partially overcome by the second method of assessment of aphid populations. Here, samples of normal terminals were removed from the trees, and the large numbers of aphids on them were counted. On a single set of these samples, at the termination of the trials, there were more than 180,000 aphids. Clearly, the counting of many such samples was out of the question, and, in the original study (16) only one such set of samples was taken, at the conclusion of the trials. However, an alternate procedure has now been devised (13) in which the number of aphids in a given weight of terminals is estimated volumetrically. By the use of this rapid method, in the experiments described in this report, aphid populations were determined at intervals during the progress of recolonization.

While the experiments were in progress the mean maximum, and minimum, temperatures were 90.3°F. and 60.1°F. respectively in a standard Stevenson screen close to the boundary of the orchard. There was no rain during the course of the experiment. Irrigation was by overhead sprinklers that wetted the trees from top to bottom; previously (16) it was by low sprinkers that wetted only the trunks and lower branches. The change in the method of irrigation had a bearing on the weathering of the deposits and will be referred to later.

[1]Contribution No. 62 Research Station, Research Branch, Canada Department of Agriculture, Summerland, British Columbia.
[2]Entomologist and Chemist respectively.

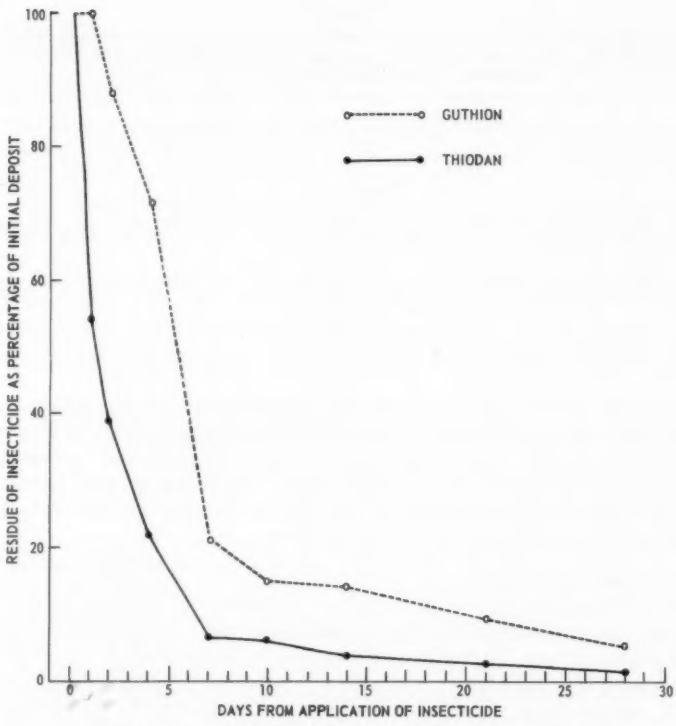


Fig. 1. Decline of residues of Guthion and Thiodan.

The insecticides that were used were Thiodan[3](6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) formulated as a 50 per cent wettable powder, and Guthion[4][*0,0*-dimethyl *S*-(4-oxo-benzotriazine-3-methyl)phosphorodithioate] as a 25 per cent wettable powder. Both materials were applied as dilute sprays at a concentration of 0.05 per cent of active ingredient. The trees were sprayed with an excess of fluid. In the chemical determination of spray deposits a colorimetric procedure was used (5,12) after the samples had been stripped with *n*-hexane. Other details regarding methods are given in the earlier paper (16).

Results

Chemical residues

Chemical residues, of Thiodan and Guthion, analysed immediately after the freshly applied deposits had dried, averaged 2.19 and 2.04 micrograms per square centimetre respectively. The subsequent decline in the deposits is shown in Fig. 1 where the values are expressed as a percentage of the initial figures.

It will be seen that the deposits of Thiodan declined to half the initial concentration in approximately 1.2 days. The persistence of Thiodan, then, was little better than that of Diazinon (16), the least persistent material in these investigations. Guthion, by contrast, was decidedly more persistent because it was 5.4 days before the deposit had declined to half its initial value. Sevin (16)

[3]Niagara Chemical Division, Food Machinery and Chemical Corporation, Middleport, N.Y., U.S.A.
[4]Chemagro Corporation, Kansas City, Mo., U.S.A.

TABLE I

Recolonization of aphid-free apple leaves. First method of estimation of aphid populations; direct field counts of aphids present on tagged leaves of debudded terminals. Figures show mean aphids per leaf.

Treatment	Days after application of insecticide							
	0	2	4	7	10	14	21	28
Thiodan, 50% wettable powder, 0.5 lb. per 100 Imp. gal.	0.00	0.05	4.11	8.61	20.1	36.8	27.6	44.1
Guthion, 25% wettable powder, 1.0 lb. per 100 Imp. gal.	0.00	0.04	2.90	5.31	16.3	25.9	38.0	48.9
Check — untreated	0.00	0.20	2.85	10.10	17.9	25.0	35.3	48.6

had previously shown approximately the same degree of persistence. On the fifth day after the trees had been sprayed overhead sprinklers were turned on, in the routine course of orchard operations. This coincided with a sharp drop in Guthion residue; in the previous work, in which Sevin was studied, low sprinklers were used. Other work (17) has, in fact, shown that heavy sprinkling of foliage can remove deposits of both Sevin and Guthion.

Recolonization by aphids

The results of the present investigation are shown in Tables I and II. These indicate the progress of reinfestation as revealed by the two methods of assessment. Though there are signs of a slightly lower aphid population on the trees treated with Guthion, the differences were never statistically significant ($P>0.05$); in any case, only a very sizeable reduction has any economic significance. The previous investigations (16) showed that, of the three materials then examined, only Sevin was effective in slowing up the rate of recolonization of aphid-free trees. Nevertheless, insofar as initial kill is concerned, all the materials so far examined have been widely accepted as effective aphicides.

Discussion

The anomaly that four out of five insecticides, all proved aphicides in terms of initial kill, should have no residual toxicity to apple aphids merits some thought and discussion. The inadequacy of Diazinon, and Thiodan, in preventing reinfestation is not surprising in view of the rapid decline in deposit that was detected by chemical analysis. However, explanation of the ineffectiveness of Guthion and Trithion, and the relative effectiveness of Sevin, is not easy. Two broad hypotheses suggest themselves.

First, for a persistently effective aphicide, it may be a necessary requirement that it have some degree of systemic action. Against the apple aphid, unquestionably systemic materials, such as dimethoate [*0,0*-dimethyl *S*-(N-methylcarbamoylmethyl) phosphorodithioate] have a longer residual action than even Sevin (14, 15). Aphids have a habit of life that makes them peculiarly susceptible to an insecticide with systemic action, and, at the same time, less vulnerable to the action of a dried deposit of contact insecticide. Aphids feed by inserting their stylets into the region of the vascular bundles of the leaves, and extracting sap (3). They feed mainly on amino acids in the sap, and, in order to secure adequate amounts of these food materials, they have to filter immense quantities of sap (8, 11). The unwanted portion of the sap, consisting mainly of carbohydrates in water solution, is excreted as honeydew (9, 10). It has been shown

TABLE II

Recolonization of aphid-free apple leaves. Second method of estimation of aphid populations. Mean numbers of aphid present in 25-gram samples of terminal leaves. Numbers estimated by volumetric method where they exceeded 200 per saaple.

Treatment	Days after application of insecticide				
	0	7	14	21	28
Thiodan, 50% wettable powder, 0.5 lb. per 100 Imp. gal.	0.00	121	490	1290	2910
Guthion, 25% wettable powder, 1.0 lb. per 100 Imp. gal.	0.00	103	390	1570	2530
Check — untreated	0.01	187	510	1400	2890

that once aphids have inserted their stylets they are force-fed by the pressure of the sap, for, if the aphid stylets are amputated, but left *in situ* in the leaf, the stylets continue to emit sap for hours afterwards (8, 9). Since systemic insecticides are mainly carried within the vascular system of the plants, the potential capabilities of such chemicals as aphicides are obvious. Since aphids feed on readily available and predigested material, without much need to forage for food, they have an essentially "degenerate" parasitic existence. Once they have established a feeding site they have little need to move except when forced by the pressure of population. The relative immobility of aphids means that they are not likely to be harmed by deposits of dried insecticide. On the other hand actively moving pests, such as tetranychid mites, come in contact with such deposits in their foraging activities, and have a much greater chance of getting a lethal dose of pesticide. Evidence has been obtained (15) that residues of Trithion, seven days old, though non-toxic to aphids at this age of the deposits, are toxic to protonymphs of the European red mite, *Panonychus ulmi* (Koch). Conventional non-systemic aphicides apparently kill aphids almost solely by falling directly on the bodies of the insects as they are applied, or by acting as fumigants.

The truly persistent effect of Sevin might result from some limited systemic effect that occurs when the material is sprayed on foliage. Though the means whereby molecules may be translocated through a plant are various and complex (1, 6, 7), a requirement for simple systemic action, generally characteristic of systemic insecticides, is that the chemical be either soluble in water, or, have some potent water-soluble breakdown product. Thiodan is stated to be insoluble in water, Guthion and Trithion, "practically insoluble" while Diazinon has a solubility of 0.004 per cent (4). The latter material, however, probably has too short a life for systemic properties, if present, to take effect. Guthion has been shown to penetrate into leaves, but, apparently, in amounts too small to be toxic to insects (6). Sevin is stated to have a solubility in water of not more than 0.1 per cent (18). But even if its solubility were less than half of that, it nevertheless represents a potent concentration of insecticide. Many foliar sprays are applied at concentrations of 0.025 per cent or less. Though Sevin is stated (4) to have some systemic action, the source of the evidence for the statement is not clear. The results obtained in this series of experiments provide some additional, but purely circumstantial, evidence for the statement.

The other hypothesis to explain our results is that, although analysis may show that there has been no chemical change in the identified deposit, weathering processes in the field may have changed the physical form of the deposit in such

a way that old residues of some compounds are innocuous to aphids, but those of others are not. Here we are concerned not only with the properties of the chemicals themselves, but, also with those of the formulations in which the chemicals are available. Physical weathering of pesticides on foliage has been but little studied (2). Yet it is clear, from basic investigations on insect toxicology, that size, shape, cohesion, and coverage of crystals, and of amorphous deposits, on test surfaces, are important factors in the effectiveness of pesticides. So, also, is the spatial distribution of the pesticide particles on the leaves; that is, their statistical regularity, randomness or patchiness. The depth to which particles become sunk into the waxy covering of the leaf, or invaginated into the outer layer of leaf tissue, is also likely to be important.

All these factors will be affected, in varying degree, by the weathering processes of wind, rain, sunlight and temperature fluctuations; just as on a geological scale such processes mould, alter and erode surface rocks. A freshly applied deposit of a wettable powder formulation, for instance, is likely to have some resemblance to a dust deposit, in that an outer portion of the fresh residue would be expected to be easily removed, either by moving insects or by weathering agencies. An older deposit, to judge by the levelling off of the persistence curves, probably consists of a residuum so eroded, or so incorporated into the leaf surface, as not to be easily removed by further weathering, — or by insects.

But many of the details of the changes that occur can only be speculated upon at the moment. In an effort to study some of these matters more deeply equipment is being constructed that will make it possible to subject insecticide deposits to controlled, simulated weathering conditions. The deposits will then be studied by bioassay, chemical analysis and physical microexamination. This approach will be the next phase in this series of investigations.

Summary

Aphid-free apple trees were sprayed with Thiodan, or Guthion, or left unsprayed. Other trees nearby, heavily infested with apple aphid, acted as sources of recolonization of the experimental trees. Recolonization was as rapid on the sprayed, as on the unsprayed, trees. The results confirmed previous findings, with other chemicals, that dried, aging deposits of non-systemic, non-fumigant, aphicides rarely have any persistent aphicidal effect. The findings are discussed, both in relation to the habits of aphids, and to the action of weathering agencies on the toxicity of insecticide residues.

References

(1) Bennett, S. H. 1957. The behaviour of systemic insecticides applied to plants. *Ann. Rev. Ent.* 2: 279-296.

(2) Gunther, Francis A., and Roger C. Blinn. 1956. Persisting insecticide residues in plant materials. *Ann. Rev. Ent.* 1: 167-180.

(3) Kennedy, J. S., and H. L. G. Stroyan. 1959. Biology of aphids. *Ann. Rev. Ent.* 4: 139-160.

(4) Martin, Hubert. 1958. Guide to the chemicals used in crop protection. 3rd ed., Suppl. 1. Can. Dept. Agr., Ottawa.

(5) Meagher, W. R., J. M. Adams, C. A. Anderson, and Daniel MacDougall. 1960. Colorimetric determination of Guthion residues in crops. *J. Agr. Food Chem.* 8: 282-286.

(6) Mitchell, J. W., B. C. Smale, and R. L. Metcalf. 1960. Absorption and translocation of regulators and compounds used to control plant diseases and insects. *Advances in Pest Control Research* 3: 359-436.

(7) Mitchell, J. W., I. R. Schneider, and H. G. Gauch. 1960. Translocation of particles within plants. *Science* 131: 1863-1870.

(8) Mittler, T. E. 1957. Studies on the feeding and nutrition of *Tuberolachnus saligmus* (Gmelin) I. *J. Exp. Biol.* 34: 334-341.

(9) Mittler, T. E. 1958. Studies on the feeding and nutrition of *Tuberolachnus salignus* (Gmelin) II. *J. Exp. Biol.* 35: 74-84.
(10) Mittler, T. E. 1958. Studies on the feeding and nutrition of *Tuberolachnus salignus* (Gmelin) III. *J. Exp. Biol.* 35: 626-638.
(11) Mittler, T. E. 1958. The excretion of honeydew by *Tuberolachnus salignus* (Gmelin). *Proc. Roy. Ent. Soc. (London)*, (A) 33: 49-55.
(12) Phillips, W. F., and M. E. De Bendedictus. 1954. Sodium reduction technique for microdetermination of chlorine in organic insecticides. *J. Agr. Food Chem.* 2: 1226-1228.
(13) Pielou, D. P. Note on a volumetric method for the estimation of the numbers of apple aphid, *Aphis pomi* DeG. on apple foliage. *Can. J. Plant Sci.* (In press).
(14) Pielou, D. P. The control of apple aphid on dwarf apple trees with bark applications of dimethoate. *Can. J. Plant Sci.* (In press).
(15) Pielou, D. P., and R. S. Downing. 1958. Trithion as an orchard insecticide. *Proc. Ent. Soc. British Columbia* 55: 17-23.
(16) Pielou, D P., and K. Williams. The effectiveness of residues of insecticide in preventing reinfestation of apple leaves by apple aphis, *Aphis pomi* DeG. *Canadian Ent.* 1961. 93: 93-101.
(17) Williams, K. Note on the effect of rain and sprinkler irrigation on the persistence of spray residues of Guthion and Sevin. *Can. J. Plant Sci.* (In press).
(18) Union Carbide Chemicals Company. 1958. Sevin insecticide. Bull. White Plains, N.Y.

(Received February 17, 1961)

Effects of Different Diets of a Host, *Agria affinis* (Fall.) (Diptera: Sarcophagidae), on the Development of a Parasitoid, *Aphaereta pallipes* (Say) (Hymenoptera: Braconidae)

By H. L. House and J. S. Barlow
Entomology Research Institute for Biological Control, Research Branch
Canada Department of Agriculture, Belleville, Ontario

Introduction

Agria [= *Pseudosarcophaga*] *affinis* (Fall.) and *Aphaereta pallipes* (Say) make an excellent host-parasitoid couple for a determination of effects of host diet on a parasitoid. The anatomy, life history, and behaviour of these insects have been described (Salkeld, 1959; Coppel *et al.*, 1959). Moreover, *A. affinis* can be reared axenically on chemically defined diets and it is readily attacked in the laboratory by *A. pallipes*, a parasitoid of the onion maggot, *Hylemya antiqua* (Meig.). This parasitoid deposits eggs into the body cavity of its host and these increase in size: the duration of the egg stage depends on the age of the host larva when parasitized (Salkeld, 1959).

This paper shows that dietary amino acids and dextrose of the host are implicated in some mechanism that affects parasitoid survival.

Materials and Methods

Aphaereta pallipes were obtained from a laboratory culture propagated on *Agria affinis*, which were fed on pork liver, and maintained as adults on sugar and water.

House and Barlow (1958) reported a diet for the house fly, *Musca domestica* L., containing 19 amino acids, dextrose, ribonucleic acid, cholesterol, five fatty acids, Tween 80 (polyoxyethylene sorbitan monoleate, Atlas Powder Co. Ltd., of Canada, Brantford, Ontario), eight salts, 10 *B*-vitamins, agar, and water. The composition of this diet, but with .75 per cent agar, was the basis of the experimental diets for the host *A. affinis* in the present work, except diet 1 contained the amino acid mixture at a level of 3.0 per cent and dextrose at 0.5 per cent; in diet 2 the amino acids were 2.0 per cent, the dextrose, 4.0.

Host larvae were obtained and reared aseptically on the diets until 50 per cent of them reached the third instar, as previously described (House and Barlow, 1956). One day later 40 larvae were removed from each diet and put singly into a stoppered glass tube containing a number of gravid female *A. pallipes*. After attack by one female the host larva was removed, washed in 2.5 per cent formalin, rinsed in sterile water, and returned to its diet to finish feeding. Four days later it was transferred to a clean test tube in which pupation usually occurred by the next day. Nine replicates were done at different times. The temperature was controlled closely to about 22.5° C. The relative humidity was controlled to about 60 per cent, except during the first four replicates.

The few host larvae dead 24 hours after parasitization were discarded. Records were kept of the number of host puparia from which living *A. pallipes* emerged, of the numbers that emerged, and of the sex of the emergent progeny. Also noted were the times between parasitization and pupation of the host and between parasitization and parasitoid emergence. The remaining hosts were dissected 24 days after parasitization, as emergence seemed completed, and the number containing dead and living *A. pallipes* were determined.

The results were analysed statistically by means of the sign test in which the probability of significant differences between the results are determined by application of binomial confidence limits (Dixon and Massey, 1957). This technique was more appropriate than the *t* test as faulty humidity control during the first four replicates resulted in data of different magnitude and variance than that of the last five assays.

Results

Aphaereta pallipes emerged from nearly 55 per cent of the parasitized hosts on diet 2 (amino acids, 2.0 per cent; dextrose, 4.0), and from about 44 per cent of those on diet 1 (amino acids, 3.0 per cent; dextrose, 0.5). Eight out of nine times emergence occurred from a greater percentage of hosts on diet 2 than on diet 1. The probability of this, or one similarly or more remote from an expected 50-50 distribution, happening by chance is less than five per cent.

Dissection of parasitized hosts from which no emergence had occurred accounted for the remaining parasitoids as follows: on diet 1, about 32 per cent of the total parasitized hosts contained only dead *A. pallipes* and 24 per cent contained living; on diet 2, about 25 per cent contained dead and 20 per cent living. In fact seven replicates of diet 1 had more dead than the comparative replicates of diet 2, but these results were not statistically different, $P > .05$.

Moreover, the average number of emergent *A. pallipes* was 15 ± 7 on each diet, and on each about 60 per cent of the emergent progeny were females. The time from parasitization to host pupation and from parasitization to parasitoid emergence was about six days and 14 days, respectively, on each diet. These data are more or less in accord with those of Salkeld (1959) on the natural host *Hylemya antiqua*.

Discussion and Conclusions

Several workers showed that slight changes in the composition of food have marked effects on growth and development of an insect (House, 1958, 1961). But in this work the effects of the two diets on growth and development of *Agria affinis* may be considered to be very much alike as only individuals that matured at the same rate were used.

Von Brand (1952) pointed out that the diet of the host can affect intestinal parasites. It has been shown that the food of host insects in natural environments has various effects on parasitoids. For example, with good nutrition of the host

Porthetria dispar (L.), such as on the apple tree, the parasitoids *Parasetigena* [= *Phorocera*] *silvestris* (R.-D.) and *Sturmia scutellata* (R.-D.) are distinguished by great viability; in the weakened host, such as of nutrition on oak, the growth of the parasitoids is depressed in so far as weight, fat content, and survival (Sapiro, 1956). Mortality of two species of hymenopterous parasitoids was highest during immature stages in the host *Aonidiella aurantii* (Mask.) on sago palm, but the parasitoids were larger, predominantly female, lived longer, and were more prolific from the host on yucca leaves (Smith, 1957). Our work also indicates that tissue parasitoids can be affected by host diet, at least in so far as the incidence of emergence of the parasitoid *Aphaereta pallipes* depended upon the diet of the host *A. affinis*. The actual mechanism for this effect is not clear, though some effects of diet on the host are known.

The amino acids in the haemolymph of *A. affinis* may be affected quantitatively by those in the diet (Villeneuve, unpublished), and quantitative variations in the sugar content of the diet result in corresponding changes in the haemolymph (Barlow and House, 1960). Thus one may expect the highest haemolymph-sugar concentrations in the host on diet 2 and the highest haemolymph-amino acid concentration in the hosts on diet 1. Both sugar and amino acids contribute much to the osmotic pressure of the haemolymph of the host, which is the microenvironment of the parasitoid. But the diets used for the experiment were designed to produce the same osmotic pressure in the haemolymph of *A. affinis*: about 8.4 atmospheres (House and Barlow, unpublished). This then is not likely a factor responsible for the different results. Possibly high sugar concentrations increase and high amino acid concentrations decrease the food value of host tissue for *A. pallipes*. Unfortunately, however, nothing is known about the actual nutritional requirements of *A. pallipes*.

The new evidence in this paper shows that dietary amino acids and dextrose are implicated in the mechanism, probably nutritional, by which the food of the host affects the parasitoid. But until the nutritional requirements of the parasitoid are known no positive correlation can be made. This work and others, with that of Leius (1960) on the feeding requirements of adult parasitoids, provide evidence that food may determine the facility and rate of establishment of parasitoids for biological control.

Summary

When mature dipterous host larvae, *Agria affinis* (Fall.), reared on different chemically defined diets were parasitized by the braconid *Aphaereta pallipes* (Say), the effects of the host diet consisting of 3.0 per cent of amino acids and 0.5 per cent of dextrose were such that greater mortality and unsuccessful emergence of the parasitoid resulted in a greater incidence of emergence from hosts on the diet with 2.0 per cent of amino acids and 4.0 per cent of dextrose. The mean number of emergents per event, about 15; development time, about 14 to 15 days; the sex ratio, about 60 per cent female were the same for each diet. Nine replicates of the tests were done involving a total of about 600 host larvae.

Acknowledgments

We are indebted to Mr. J. L. Villeneuve, formerly of this laboratory, for permission to mention results of his work; to Dr. P. Robinson, Chief, Statistical Research Service, Research Branch, Canada Department of Agriculture, for assistance on statistical technique; and to Mrs. D. A. Chant and Messrs. G. A. Denyes and R. R. Williams for extraordinary assistance in rearing and handling the insects during the assays.

References

Barlow, J. S., and H. L. House. 1960. Effects of dietary glucose on haemolymph carbohydrates of Agria affinis (Fall.). *J. Insect Physiol.* 5: 181-189.

Coppel, H. C., H. L. House, and M. G. Maw. 1959. Studies on dipterous parasites of the spruce budworm, *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae). VII. *Agria affinis* (Fall.) (Diptera: Sarcophagidae). *Can. J. Zool.* 37: 817-830.

Dixon, W. J., and F. J. Massey, Jr. 1957. *Introduction to Statistical Analysis*, p. 280, 2nd ed. McGraw-Hill Book Company, Inc. New York, N.Y. 488 pp.

House, H. L. 1958. Nutritional requirements of insects associated with animal parasitism. *Exptl. Parasitol.* 7: 555-609.

House, H. L. 1961. Insect nutrition. *Ann. Rev. Entomol.* 6: 13-26.

House, H. L., and J. S. Barlow. 1956. Nutritional studies with *Pseudosarcophaga affinis* (Fall.), a dipterous parasite of the spruce budworm, *Choristoneura fumiferana* (Clem.). V. Effects of various concentrations of the amino acid mixture, dextrose, potassium ion, the salt mixture, and lard on growth and development; and a substitute for lard. *Can. J. Zool.* 34: 182-189.

House, H. L., and J. S. Barlow. 1958. Vitamin requirements of the house fly, *Musca domestica* L. (Diptera: Muscidae). *Ann. Entomol. Soc. Am.* 51: 299-302.

Leius, K. 1960. Attractiveness of different foods and flowers to the adults of some hymenopterous parasites. *Can. Entomologist* 92: 369-376.

Salkeld, E. H. 1959. Notes on anatomy, life-history, and behaviour of *Aphaereta pallipes* (Say) (Hymenoptera: Braconidae), a parasite of the onion maggot, *Hylemya antiqua* (Meig.). *Can. Entomologist* 91: 93-97.

Sapiro, V. A. 1956. The influence of the nutritional regimen of the host on the growth of certain insect parasites (in Russian). *Zhur. Obshch. Biol.* 17: 218-227. ([original not seen] re: *Biol. Abst.* 38778, 1958).

Smith, J. M. 1957. Effects of the food plant of California red scale, *Aonidiella aurantii* (Mask.) on reproduction of its hymenopterous parasites. *Can. Entomologist* 89: 219-230.

Von Brand, T. 1952. *Chemical Physiology of Endoparasitic Animals* pp. 215-55. Academic Press, Inc. New York, N.Y. 339 pp.

(Received July 11, 1961)

Notes on Three European Diptera Recently Discovered in Canada

By G. E. SHEWELL

Entomology Research Institute, Research Branch
Canada Department of Agriculture, Ottawa, Ontario

Pollenia vagabunda (Mg.) (Calliphoridae)

Distinguished from the common 'cluster fly', *Pollenia rudis* (Fab.) as follows: Mesonotum with a median stripe anterior to transverse suture (readily seen with naked eye in oblique posterior view). Basicosta black (in *rudis* it is reddish-brown in female but inclined to be darker in male especially towards the base). Tessellation of abdomen less broken, the contrasting pollinose areas larger and more regular (rectangular) in outline. Abdominal pollen cinereous with bluish reflection (dull yellowish in *rudis*). Male genitalia (Figs. 1-3) with forceps and aedeagus longer and more slender.

Several specimens of this species have recently been found both in material submitted for identification and in general collections made by officers of the Entomology Research Institute. It has undoubtedly been introduced by human agency and, being readily confused with *P. rudis*, its introduction may have occurred earlier than the present records suggest. The small numbers taken so far indicate, however, that it is not yet well established. The immature stages of *P. vagabunda* are unknown. Séguy (1934) says that there are two generations

annually in Europe, one in the spring and the other in the fall, the adults being commonest in early spring. His illustration of the male aedeagus apparently does not agree with mine which has been compared with British specimens determined by Van Emden.

Canadian records are as follows: PRINCE EDWARD ISLAND. Brackley Beach, 30.VII.1940, J. McDunnough, 5 ♂♂, 1 ♀. Stanhope, 17.VIII.1947, R. H. Wigmore, 1 ♂ 1 ♀. NOVA SCOTIA. Deep Brook, 27.IV.1958, A. D. Pickett, 2 ♂♂ (in house with *P. rudis*). BRITISH COLUMBIA. Langford, 11.VII.1960, D. Evans, 1 ♀.

Pollenia vespillo (Fab.), a species distinguished by its shining black abdomen, has several times been cited as occurring in North America, these citations being based on the record of Walker (1849). However, Mr. H. Oldroyd of the British Museum has recently informed me that all the Canadian specimens so assigned by Walker are of *rudis*.

Urophora jaceana (Her.)
(Trypetidae)

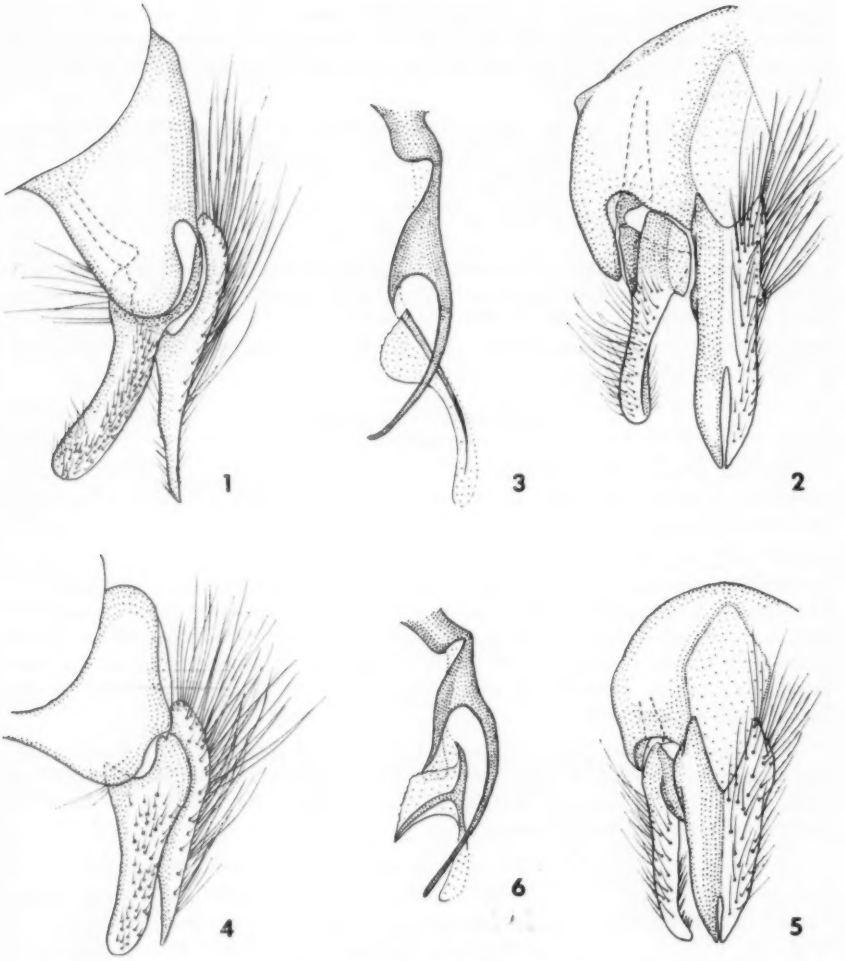
Shining black. Head excepting occiput, lateral margins of thorax, disc of scutellum, halteres and legs yellow. Disc of mesonotum yellowish to greyish pollinose. Bristles and hairs black. Wing whitish-hyaline with black crossbands. Length: male 3.0-4.0 mm., female 4.5-6.0 mm.

This species has no close relatives native to North America. Structurally it is nearest to *Rhynencina* Johns., a genus of yellow species with greatly elongated head, strongly produced oral margin and long slender geniculate proboscis. Both genera fall within Hendel's (1927) concept of the tribe Myopitini of the subfamily Trypetinae, *Rhynencina* being apparently rather closely related to the European *Myopites* Bréb.

In its body-colour and wing-pattern, *U. jaceana* superficially resembles certain species of *Rhagoletis* (e.g. *berberis* Cn.). The head, although longer in relation to its height, is much like *Rhagoletis* in shape. Main differences between the two genera are tabulated below.

	Urophora	*Rhagoletis*
Fronto-orbital bristles	one upper, two lower	two upper, three lower
Third antennal segment	apex blunt above	apex pointed above
Anal cell	apex evenly convex	lower apex produced, triangular
Basal wing-band	transverse from costa to anal cell	oblique from humeral crossvein to anal cell
Middle wing-band	covering distal half of stigma	covering entire stigma
Mesonotal hairs	black	yellow or white
Ovipositor	longer than rest of abdomen	much shorter than rest of abdomen

Although not previously recorded in print, the presence of this species in eastern Canada has been noted for some years. The larvae live in flowerheads of *Centaurea nigra* L. (black knapweed) a species introduced from Europe and now widespread in the Maritime Provinces and Gaspé and also reported from northeastern U.S., Ontario and B.C. The fly has no doubt been introduced along with its host plant. Wadsworth (1914) has published on the life-history (as *Urophora solstitialis* L.) and gives a fairly good illustration of the adult female fly.



Figs. 1-3. *Pollenia vagabunda* (Mg.). 1. Male hypopygium, left lateral view. 2. The same, posterior view. 3. Aedeagus, left lateral view. Figs. 4-6. The corresponding structures of *Pollenia rudis* (Fab.).

Canadian records of *U. jaceana* are as follows: NEWFOUNDLAND. Avondale, St. Johns, Tors Cove, 12.VI.-22.VII. NOVA SCOTIA. Baddeck, Imperoyal, Kentville, Tusket, Waverly, 5.VI.-9.VII. A total of 45 ♂♂, 33 ♀♀. First taken at Kentville, N.S. in 1923 (R. P. Gorham) and at St. Johns, Nfld. in 1949 (W. J. Brown).

Minettia rivosa (Mg.)
(Lauxaniidae)

Head and thorax dull brownish or greyish pollinose. Mesonotum with dark brown vittae. Legs dark brown. Abdomen light brown with dark brown interrupted cross-bands. Length of body 4.0 mm., of wing 4.5 mm.

Frons light brown; orbits and triangle greyish; a dark brown transverse bar anteriorly, in front of which the anterior margin is yellowish. Face and cheeks brownish with sparse grey pollen; lower inner margin of parafacial narrowly black; dark brown orbito-antennal spots present. Antenna light brown; arista black. Palpus and proboscis dark brown.

Mesonotum with four narrow dark brown vittae, one on either side of each dorsocentral row, the outermost commencing behind transverse suture. Disc of scutellum greyish to brownish pollinose, margin yellowish with conspicuous dark brown mark on each side below. Haltere pale brownish yellow. Wing membrane faintly brown-tinged; veins light brown. Coxae and femora dark brown, subshining; tibiae except apices, and tarsi paler; hind tibia with inconspicuous dark subbasal ring.

Abdomen subshining light reddish brown; middle of second to fourth segments with broad shining dark brown bands that are broadly interrupted medially. Collin (1948) has illustrated the male and female genitalia.

This is the type species of *Minettia* R.-D. It is structurally very similar to *Minettia lupulina* (Fab.) and related species both here and in Europe, but can be readily separated from all described Nearctic species by the vittate thorax and the generally dull brownish rather than bluish colour of the thoracic pollen. It has recently become established in several localities in the lower Fraser Valley in British Columbia close to the U.S. border. There are several large commercial nurseries in the area and it is possible that the species has been introduced in soil around roots of imported evergreens. The larvae of Lauxaniidae are believed to be mostly saprophagous but it must be admitted that very little is known about the biology of the group. It is in fact surprising that *Minettia lupulina* (Fab.) which is one of the commonest and most widespread acalyptrate flies in Canada has not yet been reared.

Canadian records of *M. rivosa* are as follows: British Columbia. Douglas, Mission City, Pitt Meadow, Ruskin, 2.VI.-21.VII. A total of 10 ♂♂, 5 ♀♀. First taken at Mission City, 1953 (W. R. M. Mason *et al.*).

Summary

Pollenia vagabunda (Mg.) (Calliphoridae), *Urophora jaceana* (Her.) (Trypetidae), and *Minettia rivosa* (Mg.) (Lauxaniidae) are recorded in N. America for the first time. Brief descriptions and comparisons with native species are given.

Acknowledgments

I am indebted to Mr. H. Oldroyd, British Museum, London, for comparing the male genitalia of Canadian *Pollenia vagabunda* (Mg.) with European material; also to Mr. A. T. S. Wilkinson, Canada Department of Agriculture, Research Station, Vancouver, for information on horticultural nurseries in the lower Fraser Valley.

References

Collin, J. E. 1948. A short synopsis of the British Sapromyzidae (Diptera). *Trans. Roy. Ent. Soc. London* 99: 225-242.

Hendel, F. 1927. Trypetidae. *In* Lindner. *Die Fliegen der Palaearktischen Region* 49: 1-221.

Séguy, E. 1934. Contribution à l'étude du genre *Pollenia* R.-D. *Rev. Française d'Ent.* 1: 44-51.

Wadsworth, J. T. 1914. Some observations on the life-history and bionomics of the knapweed gall-fly *Urophora solstitialis* Linn. *Ann. Appl. Biol.* 1: 142-169.

Walker, F. 1849. List of the specimens of dipterous insects in the collection of the British Museum. Pt. 4. London.

(Received May 18, 1961)

Disease in a Field Population of the Introduced Essex Skipper, *Thymelicus lineola* (Ochs.) (Lepidoptera: Hesperiidae)

By G. E. Bucher and A. P. Arthur
Entomology Research Institute for Biological Control, Research Branch
Canada Department of Agriculture, Belleville, Ontario

The Essex skipper, *Thymelicus* (*Adopaea*) *lineola* (Ochs.), is said to have been introduced from Europe to the area of London, Ontario, about 1910 but attracted little attention until 1955 (MacNay, 1956). Since then it has been found over most of southern Ontario (MacNay, 1959) and presently is causing damage to fields of timothy, *Phleum pratense* L., near Priceville, Ontario. As the larvae eat the leaves of timothy and orchard grass, *Dactylis glomerata* L., this species is a potential pest of forage crops.

On June 9, 1960, larval collections were made by sweeping in a heavily infested pasture containing timothy and orchard grass on the Aldcorn property southwest of Priceville. Though no mortality was observed in the field, 30 per cent of the mature larvae reared in the laboratory died before pupating.

A sample of 50 larvae of mixed age from this collection was examined for disease. About 60 per cent contained large, motile, rod-shaped bacteria in the lumen of the gut and in the fluid that they readily regurgitated. In 66 per cent, cells of the midgut epithelium were infected with a cytoplasmic polyhedrosis. Many of the larvae contained both infections and about 20 per cent were apparently disease-free when examined. Observations indicated that the population had recently acquired the infections. For example, none of the larvae contained spore-bearing forms of the bacterium and only a few contained large numbers of vegetative rods; in most larvae the virus infected only a small number of cells and the virus polyhedra were tiny and apparently in process of formation.

A second sample of 50 immature larvae was reared in the laboratory and observations made daily. After one day the regurgitation fluid of most larvae contained numerous large motile bacteria and after two days these bacteria began to sporulate. Larval deaths occurred in two to eight days and only eight per cent pupated. Gut virus was diagnosed in 60 per cent of the dead larvae but characteristic rods or spores of the bacterium were rarely recognized with certainty in dead insects. In the remaining 40 per cent secondary bacterial infection interfered with positive diagnosis of the primary infections.

On June 24, 1960, three samples on the Aldcorn plot showed the mean skipper population to be 236 per square yard of which 31 per cent were living pupae, two per cent were dead pupae, 40 per cent were dead larvae, and 27 per cent were living larvae. All the living larvae died within four days without pupating. Dead larvae from the field were very short and dry and the anal segments were laterally compressed. They resembled the larvae of tent caterpillars killed by the spore-forming bacterium, *Clostridium brevifaciens* (Bucher, 1957, 1961). Various small bacteria had invaded the haemocoele through the wall of the posterior midgut and produced some tissue destruction but the relatively limited multiplication of these bacteria suggested that the larvae were already rather dry before this process began. This secondary bacteriosis, however, did interfere with diagnosis of the other diseases; virus polyhedra and spore-forming bacterial rods were not found in numbers in dead insects collected in the field.

On July 1, 1960, collections were made in a second stand of timothy north of Priceville. As development of the skipper had been delayed by the high dense growth of the crop, larvae and pupae were numerous. There was no

obvious mortality in the field. A sample of 100 larvae reared in the laboratory produced 97 pupae; two larvae died with bacterial septicaemia at moulting and one larva died from a nuclear polyhedrosis virus infection of the fat, hypodermis, and tracheal matrix. There was no evidence that this population was infected with a gut virus or a spore-forming bacterium.

Vegetative rods of the bacterium were 6-10 μ long and about 1.2 μ wide and increased in diameter to about 1.8 μ at sporulation. Spores were borne subcentrally without bulging the sporangium. The bacterium resembled *Clostridium brevifaciens* (Bucher, 1961) in form and motility, and in its occurrence solely in the lumen of the host's gut, and produced symptoms in skipper larvae somewhat similar to those caused by *C. brevifaciens* in tent caterpillars. It was isolated in pure culture in broth media used for *C. brevifaciens* propagation but formed no spores in culture, grew less vigorously in broth than *C. brevifaciens*, and failed to grow on solid agar media. It is tentatively regarded as similar to but not identical with *C. brevifaciens*. Polyhedra of the gut virus were small compared with those encountered in diseases of other Lepidoptera. In purified preparations made from numerous pooled insects, the polyhedra ranged in size from 0.5 to 2.5 μ and the majority were 1.5 $\pm$ 0.5 μ. The nuclear polyhedra from a single insect were more uniform in size, most being 1.5 $\pm$ 0.2 μ in diameter.

We conclude that high mortality of the Aldcorn population was associated with the presence of two diseases caused by a gut virus and a spore-forming bacterium. From experience with similar diseases of other insects it seems doubtful if either disease can be considered the immediate cause of death. Gut viruses usually do not kill the hosts until most of the midgut epithelium is infected, but most skipper larvae died before a high proportion of gut cells were infected. The small and highly variable size of the virus polyhedra also indicated that the course of virus development was interrupted by death from another cause. In the tent caterpillar, death from infection with *C. brevifaciens* occurs only after the bacterium has produced large populations in the gut and has sporulated, but skipper larvae usually died before mass multiplication or sporulation of the bacterium had occurred. In most individuals, the direct cause of death seems to have been the secondary multiplication of various non-sporulating bacteria in the gut, followed by their invasion of the haemocoele through a midgut epithelium already damaged by two primary diseases. The primary diseases caused a condition of stress in the larvae that allowed the development of a secondary bacteriosis, which in turn interrupted the complete development of the primaries.

We have not found any previous reference to virus, bacterial, or protozoan diseases of the Essex skipper or of any other member of the Hesperiidae. The discovery of a nuclear polyhedral virus, a cytoplasmic gut virus, and a spore-forming bacterium that infect this insect opens a possible avenue of control if this potential pest increases in economic importance.

References

Bucher, G. E. 1957. Disease of the larvae of tent caterpillars caused by a spore-forming bacterium. *Can. J. Microbiol.* 3: 695-709.

Bucher, G. E. 1961. Artificial culture of *Clostridium brevifaciens* n.sp. and *C. malacosomae* n.sp., the causes of brachytosis of tent caterpillars. *Can. J. Microbiol.* In press.

MacNay, C. G. 1956. *Canadian Insect Pest Review* 34: 86.

MacNay, C. G. 1959. *Canadian Insect Pest Review* 37: 154.

(Received June 5, 1961)

Techniques for Rearing *Ips* De Geer (Coleoptera: Scolytidae)[1]

By G. R. Hopping
Forest Biology Laboratory, Calgary, Alberta

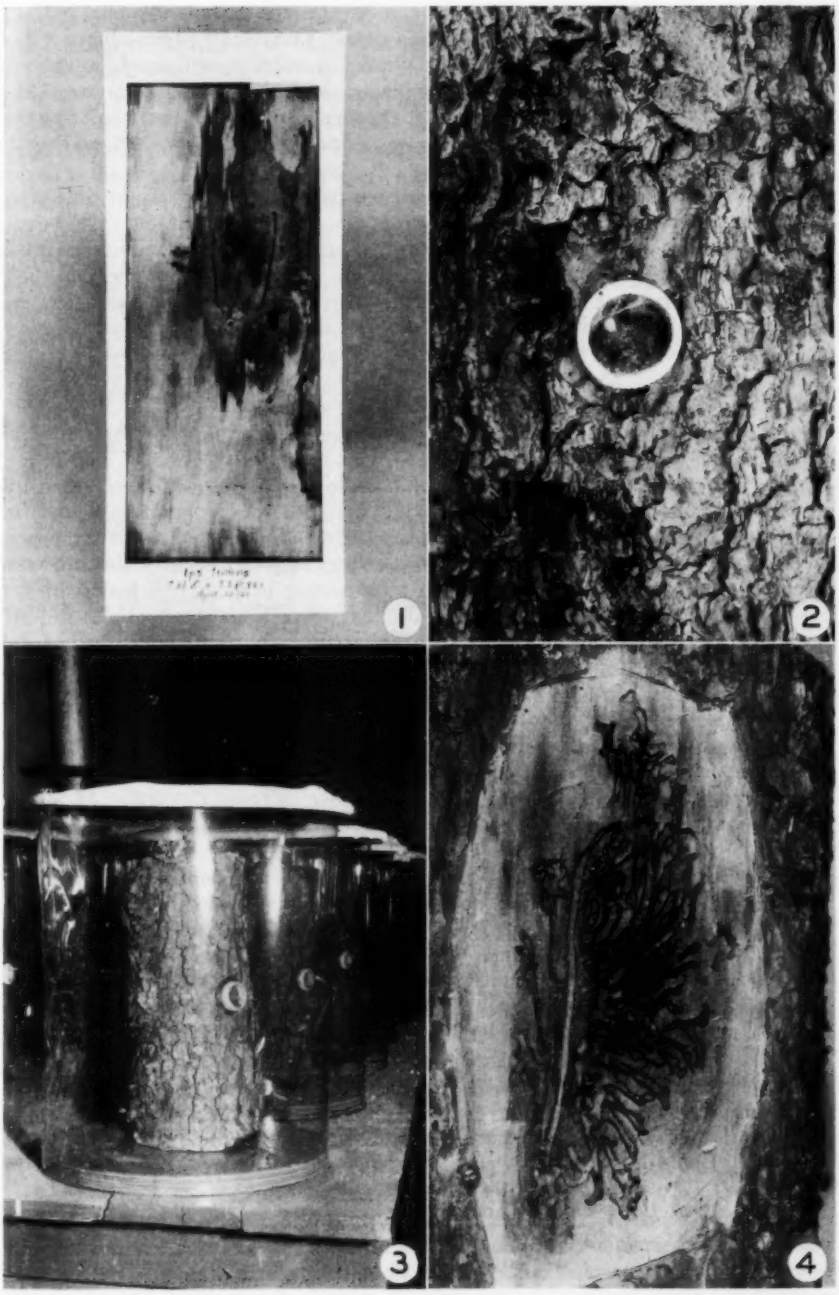
The genus *Ips* in North America contains several groups of closely related species which are at present poorly defined. Morphological characters alone do not provide an adequate basis for deciding whether some of the forms are specifically distinct or represent mere variations which may occur in the same general locality or even in the same brood. The extent of this variation can be determined only by breeding isolated pairs through successive generations combined with biological studies in the field. The present article describes techniques for rearing successive generations of *Ips* in the laboratory.

The first method employed was similar to that used by R. W. Reid (1960) during his studies of the mountain pine beetle. A rectangular piece of fresh inner bark is placed between two sheets of ⅛-inch lucite plastic; a convenient size for rearing *Ips* is six by 12 inches. This "sandwich" (Fig. 1) is sealed around the edges with adhesive tape which must be tenacious enough to prevent slippage if the inner bark dries out enough to start warping. If the seal is good, there is little moisture loss and no warping takes place. Warping can also be prevented by placing small metal clamps around the edges of the "sandwich". Reid introduces the beetles into a slot in the bottom edge of the inner bark opposite a small hole in the binding which is then taped over. When rearing *Ips*, particularly if more than one female per male is to be used, it is better to drill an entry hole through the centre of the face plate. This leaves room for the females to excavate egg galleries in several directions from the nuptial chamber. The adults are placed on the surface of the plate near the entry hole and covered with the lid of a petri dish held in place by a strip of tape. After the beetles are well into the bark beneath the face plate, the petri dish can be removed and the entry hole closed with a wooden plug. The "sandwich" is placed on an incline to give direction to the female while excavating the egg gallery.

This technique is particularly suited to observing or photographing the activities of the bark beetle during gallery construction, mating, egg laying and the development of the brood. It is not so well suited for maintaining a continuous line of descent through many generations because the broods produced are usually small. The following technique is more satisfactory for the production of reasonably large broods from isolated pairs. Sections one foot long are sawn from freshly cut logs five to eight inches in diameter. The ends of each section are dipped in melted paraffin to prevent rapid loss of moisture. Sections which were kept for two months at room temperature had inner bark moisture content of 125 to 130 per cent based on oven-dry weight. This compared with 162 to 166 per cent immediately after trees were winter cut.

A large screw eye is inserted at the centre of one end of each log to facilitate handling. At a convenient point about mid-way between the two ends, the bark surface is smoothed on an area of several square inches. Near the centre of this a "starter" hole is drilled through the bark. This is not essential but it usually speeds up the entry of the beetles into the bark. A plastic cup is placed over the entry hole and fixed to the bark surface with liquid glue. The *Ips* pair is placed in the cup through a hole in the face of it which is then plugged with a bit of match stick. (Fig. 2).

[1]Contribution No. 779, Forest Entomology and Pathology Branch, Department of Forestry, Ottawa, Canada.



Figs. 1-4. Techniques for rearing *Ips* De Geer. 1. Sandwich of inner bark between sheets of plastic. 2. Plastic cup in which the *Ips* pair is placed. 3. Plastic rearing cages. 4. Type of gallery system resulting from an isolated pair.

Under natural conditions the male excavates the entry hole and nuptial chamber and therefore is placed in the cup first. The female is introduced a day or so later when the construction of the nuptial chamber is sufficiently advanced. During the entry procedure, the log is placed on a slight incline to enable the beetles to regain their feet more easily if they roll upon their backs. After the beetles disappear beneath the bark the log section is placed on end making it easier for the beetles to eject the frass.

Broods often remain beneath the bark for considerable periods of time after becoming fully pigmented. It is not necessary to await emergence, however. The production of broods can be speeded up considerably by examining each log section approximately 40 days after placing the beetles in the plastic cup. By then the new brood are usually in the dark brown teneral stage and sometimes are nearly black. The adults are removed to petri dishes containing moist sawdust mixed with portions of fresh inner bark. Subsequently the beetles can be paired in any desired way and introduced into fresh log sections or, if necessary, they can be held for considerable periods in cold storage at about 3°C.

If an attempt is made to produce hybrids, each beetle must be removed from the pupal cell and kept isolated until paired with the species desired. This is also important if one wishes to make sure of breeding across broods rather than in-breeding. If in-breeding is the objective, isolation of individuals is not so important. Any breeding which takes place beneath the bark or while the brood is in the petri dish must necessarily be in-breeding although there is then no way to be sure whether the male selected in each pairing is the actual parent of the ensuing brood. Copulation in the petri dish has never been observed. It is quite probable that the conditions necessary for fertilization occur only during the construction of the gallery.

Each log section should be placed in a cage soon after the entry of the beetles. This prevents escape if they should bore out through the bark although this rarely happens. An inexpensive and satisfactory cage can be made as follows. A circular base, one foot in diameter, is cut from ¾-inch plywood. A sheet of 4 mil. acetate plastic is stapled to the circular base to form a cylinder 16 inches high. The vertical seam is welded with acetone and rubberoid weather stripping is sewn on the top edge of the cylinder. The lid of the cage is made by sewing a double thickness of butter cloth to a hoop made of ¼-inch plastic tubing. The hoop is made slightly larger than the top of the cage and the plastic tube is filled with BB-shot. This gives the hoop enough weight to hold the cloth covering fairly tightly against the rim of the cage. (Fig. 3). The total cost of materials for 12 cages at 1961 prices was approximately $45 or $3.75 per cage.

This method has been successful in rearing sufficiently large broods from isolated pairs for continuing generations. Some failures result for reasons not yet apparent, but some are caused through failure to pair opposite sexes in species which have no secondary sexual characters. If two males are placed in the plastic cup, they usually excavate separate entry holes. Other adults can then be substituted until a female is found. Determination of sex is easy in *I. tridens* (Mannh.), *I. engelmanni* Sw., *I. borealis* Sw., and *I. pini* (Say). It is difficult in *I. yohoensis* Sw. and in the *I. perturbatus* (Eichh.) group.

Between September 23, 1960, and the following May 10, 12 broods and four generations of *I. tridens*, and 14 broods and four generations of a species near *I. yohoensis* were reared at room temperature from isolated pairs. The number of progeny per brood varied from three to 53. *Ips* are polygamous and under natural conditions each gallery contains a male and one to five females. The average number of females per gallery system varies between species but three

is quite common. In such cases the galleries form the characteristic "tuning fork" pattern. When a pair is bred in isolation, the egg gallery is about the same length as one arm of a gallery system under natural conditions, i.e. 10 to 12 cm. (Fig. 4). Success or failure to produce a brood usually can be determined within 10 days after the beetles start to work. If eggs are being laid, abundant frass is ejected into the plastic cup. It is composed of light coloured sapwood particles mixed with darker bark particles. If egg laying fails to take place the frass in the cup is scant and usually dark brown.

The rearing of *Ips tridens* has presented a problem which first became apparent in the F_2 generation. Three of four broods produced contained 34, 24 and 17 individuals, all females. Subsequently two F_2 broods were produced consisting of females only. A possible cause of the high production of females may have been the influence of temperature (24°-26°C.) on the sex determining mechanism during breeding (Swanson, 1957).

The rearing of successive generations of *Ips* species from isolated pairs has proven its usefulness in disclosing the amount of variation within species. It enables the bio-systematic worker to be more confident in the delineation of species and in the recognition of discrete populations in the field.

References

Reid, R. W. 1960. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins (Coleoptera: Scolytidae). Ph.D. Thesis, Montana State College, Bozeman, p. 14.

Swanson, C. P. 1957. Cytology and cytogenetics. Prentice Hall Inc. p. 314.

(Received June 16, 1961)

A Sampling Cage for Aquatic Insects

By H. G. James and C. F. Nicholls

Entomology Research Institute for Biological Control, Research Branch
Canada Department of Agriculture, Belleville, Ontario

Near Belleville, Ontario, it was necessary to take quantitative samples of predators in shallow pools in field studies of the natural control of mosquitoes. To expedite this work a light-weight sampling cage was constructed. Its description follows.

The cage (Fig. 1, top) consists of an enclosure (A) and two sorting trays (B and C). The enclosure, covering one-half square metre, is of four screened frames, each 12 inches high. Each frame is of aluminum extrusions (Higgins-Homeshield Limited, Toronto, Ontario) of the types shown in details F and G. The extended flange on extrusion G, used at the right-hand side of each frame, provides a means of overlapping and fastening at the corners of the enclosure. After the frames are fastened together to form a square, pointed angle-aluminum legs (D) 16 inches long are fastened to each inside corner. Small braces are also fastened across each corner to hold the enclosure in shape.

A piece of 16-mesh galvanized screen is fitted over each enclosure frame with its edges pressed into grooves provided in the extrusions and held in place with pieces of plastic tubing (details F and G) forced into the same grooves. The lower edge of the enclosure is provided with a skirt (E) of 24-mesh nylon cloth to ensure a seal against the uneven bottom of the pool. The skirt has a weighted chain suspended in the hem of its lower edge and is fastened to the

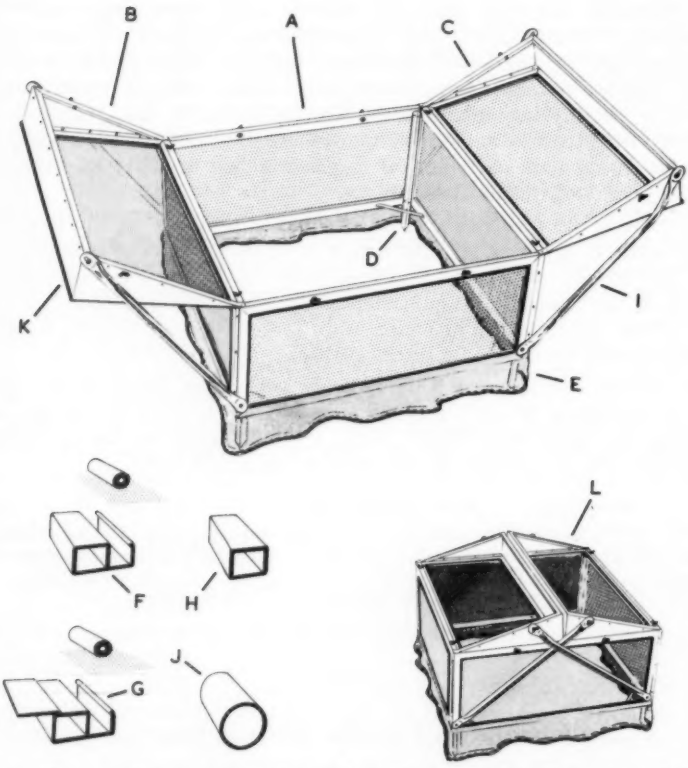


Fig. 1. Top, sampling cage set up for use in pools. Lower left, illustrations of aluminum extrusions used in construction. Lower right, cage reassembled for carrying.

enclosure by placing its upper edge in the same groove as the galvanized screen, both of which are then held in place by the plastic tube.

The sorting trays (B and C) are made with a bottom frame of extrusions G and F, a top frame of extrusion H, and a piece of sheet aluminum. Each tray is wedge-shaped, has an outer wall four inches high and a bottom of 16-mesh galvanized screen.

The trays are attached to the enclosure with bolts and wing nuts at their inner edges and with braces (I, extrusion J) at their outer edges. The bottom outer edges are positioned four inches higher than the top edge of the enclosure framework to allow any debris and excess water to return to the sample area.

To take the sample, the cage is placed in a pool and quickly pressed down at the corners into the soft bottom so that the lower edges of the enclosure framework and the skirt are in a position to prevent the escape of trapped insects. The enclosed water is hand-sieved for swimming predators and then the pool bottom is dredged and the debris spread out on the sorting trays. Aquatic beetles and other predators become active as the water drains from the debris and may be readily counted or collected.

The cage has been used in sampling pools for adults and larvae of Dytiscidae and Hydrophilidae as well as caddis-fly larvae and aquatic Hemiptera. Though

used primarily as an area sampler, the results may be expressed in terms of volume by recording also the depth of the water and the debris.

The cage may be reassembled into a more compact unit for carrying by removing the sorting trays, rotating them laterally through 180 degrees and placing them over the enclosure as shown in Fig. 1, L. The tray braces (I) are fastened in alternate positions to hold the trays onto the enclosure as a lid. When reassembled thus, the cage could also be used as an emergence cage for mosquitoes and other aquatic Diptera simply by providing a sleeve on a reinforced opening in a convenient side frame. A sponge rubber gasket (K) ensures a seal between the two halves of the lid.

(Received March 29, 1961)

Book Reviews

Der Käfer. Ein Wunder der Schöpfung. By Ewald Reitter. 206 pp., 3 figs. and 59 plates. 34 x 24 cm. Chr. Belser Verlag, Stuttgart, 1960. Price 80 DM.

This book is a fine example of virtuosity in colour photography and printing applied to beetles. With one exception the subjects are dead and pinned specimens, although this is rarely obtrusive, selected for the most part for showiness and size. With this in mind it is not surprising that two thirds of the examples are from the Scarabaeidae or Cerambycidae; other groups represented include the Adephaga, Chrysomelidae, Anthribidae, Brenthidae and Curculionidae. The insects appear to have been photographed against a background of white foamed plastic with lighting arranged to give a rather weak shadow which relieves some of the flatness usually seen in photographs from pinned specimens. The reproduction is above reproach. The only photograph from life, and perhaps the finest picture in the book, is of the larva of *Megasoma gyas* Hbst. which, at twice life size, occupies a full page. From one to ten specimens are reproduced on each right hand page. The Latin names with their meanings in German, German common names, size, sex, distribution and brief notes on the species are printed on each facing page.

Despite the sub-title and introductory quotation from the Bible most of the text, although rather elementary, is quite modern in outlook, and covers such topics as structure, evolution from the primitive insect, development, sexual dimorphism and perhaps too generously, beneficial and harmful beetles. The classification used however is that of Handlirsch, 1923, and there is no precise systematic arrangement of the plates.

The plates are followed by an appendix on the history of the study of beetles, articles on how to collect and prepare them, an index to common and Latin names and an index to authors and journals. B. Hocking

The Feeding Behavior of *Hippodamia quinquesignata* (Kirby) Larvae. By Ibrahim K. Kaddou. University of California Publications in Entomology, Vol. 16, No. 5, pp. 181-232, plate 21, 9 figs. in text. University of California Press, 1960. Price $1.00.

This monograph reports on a variety of laboratory behaviour and biological experiments using larvae of an important aphidophagous coccinellid. In addition, information is collated from 55 publications widely scattered through the literature. A number of points critical in biological control work are elucidated

for this species. For example, even though second-instar *Hippodamia* eat 22 times as many aphids per day at 86°F. as at 60°F., they only spend 12 per cent as much time in the second instar at the higher temperature. This illustrates how the same factor may produce antagonistic effects through a causal network, and thereby conceal the magnitude of its initial effects through cancellation. The monograph makes clear how painstaking and thorough research must be to accurately evaluate a biological control agent. Of several aphidophagous coccinellids tested earlier by Clausen, *H. quinquesignata* had the lowest daily consumption of rose aphids. Yet this coccinellid is one of the most important controlling aphids on various field crops in California. Clearly, "Host specificity, distribution (or tolerance limits to environmental factors), feeding capacity of the adult, fecundity, fertility, searching ability, and natural enemies" are some of the factors that should be considered in evaluating a biological control agent, as the author points out. Host preference, searching capacity and cannibalism were studied in detail by Kaddou. However, it is difficult to know how to interpret the findings without having corresponding types of measurements on several predator species. Ideally, experimental work of the type done by Kaddou would be performed as a matter of routine on all biological control agents under evaluation. Also, we need to know much more about how to relate such laboratory measurements to field behaviour of the beasts. K. E. F. WATT

A Review of the Biological Control of Insects and Weeds in Australia and Australian New Guinea by Frank Wilson. Commonwealth Agricultural Bureaux, Technical Communication No. 1, Commonwealth Institute of Biological Control, Ottawa, Canada and Farnham Royal, Bucks., England, 1960. pp. viii + 102. Price 25s, $3.75.

It is suggested in the foreword by F. J. Simmonds that this may be the first in a projected series of review of biological control work in different parts of the Commonwealth. Mr. Wilson has set the pace for such a series with a study that does justice to his knowledge and responsibilities in the field of biological control in the Australian region. He reviews in detail the history of investigations on and efforts towards the biological control of 55 invertebrate animal species or groups, mainly insects, and 10 species of weeds. Eight species or groups of animal pests are considered to be substantially reduced in status, 11 are reduced, four are doubtfully diminished, and four unaffected. In the remaining species or groups, work is not in a sufficiently advanced stage for results to be assessed. Among the ten weed categories, investigations in only five showed material enemies important enough and specific enough to be considered promising and safe for introduction to Australia. In two out of the five categories, viz., prickly pear cacti and St. John's wort, dramatic results have been achieved. Mr. Wilson concludes with short summaries of general aspects of biological control practice and evaluations of the factors affecting progress and success of biological control investigations. Because of Mr. Wilson's scientific background and long practical and responsible experience these statements are particularly useful to the general reader. The bibliography contains 558 references and there is a comprehensive index. We hope that further studies of this type will appear, as intimated by Dr. Simmonds. EUGENE MUNROE

THE RUNGE PRESS LIMITED, OTTAWA
Mailed: Friday, October 27, 1961